

HINRICHS'

ELEMENTS OF CHEMISTRY

AND MINERALOGY.

Diese Wissenschaft lässt sich nicht aus Büchern, noch auch allein durch Besuch von chemischen Vorlesungen, sondern nur durch fleissiges Arbeiten im Laboratorium erlernen.

(Translation, see Chap. VIII.)

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THE ELEMENTS
OF
PHYSICAL SCIENCE,

DEMONSTRATED BY
THE STUDENT'S OWN EXPERIMENTS
AND OBSERVATIONS.

BY
GUSTAVUS HINRICHS, A. M.

IN THREE VOLUMES.

VOLUME II.
THE ELEMENTS OF CHEMISTRY
AND MINERALOGY.
WITH TWO PLATES AND JOURNAL OF EXPERIMENTS.

DAVENPORT, IOWA, U. S.
PUBLISHED BY GRIGGS, WATSON, & DAY.

LEIPZIG: F. A. BROCKHAUS.

1871.

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AND MINERALOGY,

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Königsberg, Emden, etc., etc.

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PREFACE TO VOL. I. 61

It is generally understood by those qualified to judge, that the teaching of elementary science in our schools is not carried on in a scientific spirit. Recitation from a text book, with occasional exhibition of experiments and specimens, is not calculated to give the beginner conviction in the truth stated, or to initiate him into the method of scientific investigation.

In regard to science, our schools are not above the middle ages. Three hundred years ago students repeated the obscure statements of ARISTOTLE, of which a sample is given (454); now our students repeat the statements of their text book, without obtaining any valid ground for the conviction they are made to express.

The great work done by GALILEO for physical science in general, has not yet reached our schools. The *method of scientific research* which he first so successfully practiced, and *which alone can lead to conviction in the truth of the results obtained*, has not yet gained admission to our schools.

We venture with the present little work to knock at the doors of our schools in behalf of this method and in the interest of science. We do not advocate anything new. For two and a half centuries these very methods have been used, the grand structure of modern science has resulted, and the course of civilization has been changed thereby.

That these same methods *are* successful in the school room and with beginners, is not a mere conclusion, but a *fact* established by experience. The few series of experiments printed in the "Journal" of this volume will confirm it. The series here published have been taken from an immense material already accumulated by students in our laboratory.

But this work is so thoroughly different from those which are in general use, that we feel under great obligations to the Publishers for having ventured this publication.

Before attempting the use of this book, the student, and especially the teacher, should carefully study the *Guide* at the close of this volume.

IOWA CITY, IOWA, U. S., January, 1871.

PREFACE TO VOL. II.

These Elements of Chemistry and Mineralogy form simply a continuation of an Elements of Physics.

Laboratory practice in chemistry is universally recognized as essential; but it cannot become universal, if grand laboratories with costly apparatus are required. By excluding special and professional branches, the methods of elementary laboratory practice here given can be furnished free of charge by any school to all its pupils. See Chapter VIII. of this volume, for details.

No one should judge our chapter on mineralogy except after having tried it in precisely the manner directed. The determination by coordinates is novel, and quite satisfactory.

While writing these lines, we receive the very cordial welcome which the London "*Nature*" extends to the first volume of this course in the Elements of Physical Science. We have earnestly endeavored, also, in this second volume, to "point out the right path of discovery" to the student, and to "act on the whole as a faithful and thoroughly painstaking guide." If "*Nature*," upon examination of this second volume, gives it an equally cordial welcome, we shall feel encouraged, while amidst but too many difficulties we prepare the final revision of the concluding volume of these Elements of Physical Science — The Students' Cosmos.

IOWA CITY, U. S., Oct. 21, 1871.

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CHAPTER I.

ON HEAT.

1. THE SUN is our principal source of heat.

The heat obtained by combustion of wood and of other vegetable materials is also due to the sun; for plants require sunshine in order to grow.

2. Heat effects very remarkable changes in the substances upon which it acts.* These effects of heat may be classified as changes in volume, changes in aggregation, and changes in composition.

3. That heat effects changes in volume is a matter of common experience, and may also be shown by the following apparatus, called a thermometer.

A glass or tin flask, of about 25 cc. capacity is completely filled with water, and closed by a stopper through which passes a narrow, long tube; as the stopper is pressed down, the water rises in the tube. A centimeter scale, divided to halves, is attached to the tube. If now the flask is placed in a vessel containing hot water, the level of the water in the tube will rise. If thereafter, the flask is put into cold water, or surrounded by ice, the level will sink.

The rise and fall of the level evidently constitutes a change in the volume of the water, brought about by the heat added to, or taken away from the flask.

*The effects on our own organism, especially the production of the sensation of warmth, cannot be considered in the elements of physical science.

4. That heat produces changes in aggregation has already been demonstrated in the Elements of Physics. Articles 113 and 151.

The solid ice is by heat fused to liquid water, and the latter by additional heat changed into gaseous steam. By removing heat, steam is again condensed to water, and water frozen to ice. Iodine also is readily exhibited in these three states of aggregation by applying or removing heat. (Elements of Physics, 113.)

5. A crystal of blue vitriol gently heated in a glass tube changes to a white powder, while the colder parts of the glass tube become covered with numerous drops of water. In this case heat has changed the state of combination, the blue vitriol being resolved into a white powder and water.

6. Such changes in the composition of substances are often termed chemical processes. Changes in volume and aggregation, not affecting the composition of bodies, are distinguished as physical processes.

These latter processes shall be studied in the first two chapters, while the chemical processes will be treated of in the balance of this volume.

7. To study these different effects of heat experimentally, we must first become familiar with the various modes of applying heat for experimental purposes.

I. MODES OF HEATING.

8. For the student's experiments, the flame of a glass alcohol lamp is a sufficient source of heat. For the blow-pipe, a common candle may replace this lamp.

Illuminating gas, burnt in a Bunsen burner, is better than the above, but not everywhere accessible. If used, its flame should be turned down until suitable for the small quantities to be heated.

9. The substances to be heated are supported over the flame in vessels of glass, porcelain, or plati-

num. The vessels are either exposed to the heat direct or by means of sand bath, air bath or water bath. Charcoal is extensively used as support when the blow-pipe flame is to be applied.

10. No experiment can give a satisfactory result, unless it is performed exactly as directed. But to understand the directions, the student must be perfectly familiar with the terms used to designate the various forms of apparatus employed. Hence the student should carefully study the following pages.*

11. The glass alcohol lamp should contain good alcohol, and be provided with a sufficiently long, well-trimmed wick. At the close of the experiment, the flame is extinguished by blowing, and the closely-fitting glass-cap is put on to prevent the evaporation of the alcohol.

Carefully avoid the soiling of the wick or its support, so that the lamp burns with a pure, pale flame.

12. The Bunsen burner consists of a narrow, vertical gas-jet, surrounded by a vertical brass tube one centimeter in diameter, and partly open below. The flame formed at the top of the wide tube results from the combustion of the intimate mixture of gas and air formed in the wider tube.

This flame of the Bunsen burner is but faintly luminous, but intensely heating, and free from soot, so as to leave apparatus exposed to it clean. The common gas burners give a highly luminous flame, which deposits much soot, and hence cannot be used for experiments on heat.

13. The glass vessels used as support for substances to

*It is expected that the teacher exhibit these apparatus to the class while this subject is under consideration.

Since the student of course has to pay the cost of all apparatus he breaks, as well as the cost of the material he wastes by improper work, he will save himself much money by a very careful study of this section prior to his beginning the experiments of the next section. Besides, by avoiding breakage and waste, the student will not delay the experimental work of his fellow-students, nor cause his teacher additional trouble and vexation.

be heated, are, retorts, flasks, beakers, dishes, watch glasses, test tubes, and common glass tubes. These will readily be distinguished and described by the student, while the teacher exhibits them to the class.

All these glass vessels must be thoroughly annealed, and of uniform thickness, in order to withstand moderately sudden changes of heat.

They should be scrupulously washed (with common water*) and rinsed (with distilled water) immediately after and again before use. Those outer parts which are to be exposed to the direct influence of heat, should furthermore be wiped dry, in order to avoid breakage from the flame (or heated sand. See 18).

14. For our purposes a glass flask of 25 to 50 cc. capacity, a few watch glasses (5 cm. diam.), and three or four test tubes (1 cm. diam., 7 or 8 cm. long) are quite sufficient. A few lengths of glass tubing will also be required—some 3 mm. internal diameter, for blow-pipe work, and some 5 mm. internal diameter, for other work, such as distillation, etc.

15. Crucibles and dishes of porcelain are very useful, but not necessary for beginners, since the blow-pipe and glass tube may be substituted for the crucible, and the watch glass for the dish. Still, the teacher may exhibit some of the forms of porcelain ware in use in laboratories.

16. Platinum is used, as support for substances to be heated, in the shape of crucibles, dishes, foil, strips, and wire. Only the last three forms are required by the beginner in blow-pipe work.

We shall therefore defer the description of these forms of platinum until we take up the description of the blow-pipe, when the charcoal support also will be noticed.

*Aided by washers, consisting of a piece of sponge tied to a small stick, or pieces of paper shaken in the flask until the paper is reduced to a pulp.

17. A glass vessel to be heated is but rarely exposed to the direct flame by supporting the vessel on a triangle of iron wire above the flame. It is best to place the glass vessel on a square piece of (brass) wire-gauze, which really prevents the flame from striking the glass vessel. This property of a wire-gauze may be exhibited by pressing such a gauze down upon a flame; the flame will then appear as if cut off by the gauze.

18. Beginners will always do well to support the glass vessel on a sand bath, rather than over the direct flame, or even the gauze.

A sand bath consists simply in a thin, shallow, sheet-iron dish, partly filled with coarse sand, which has been freed from dust by washing and drying.

19. If but a moderate heat is required, or if it be essential to prevent the heat from rising above that of boiling water, the water bath is used.

In its simplest form the water bath consists of a tin cup, about 10 cm. in diameter and 6 cm. high, closed by a cover provided with a circular opening of about 5 cm. in diameter. Before use, the bath is filled about two-thirds full with water, placed over the flame, and the vessel to be heated put over the opening in the cover.

The student should be very careful to see that the water in the water bath does not get too low.

20. The air bath is a vessel of iron or copper, wherein the apparatus to be heated may be placed while the air bath is exposed to a flame. The beginner does not require this bath.

21. The preceding modes of heating correspond to the application of heat by boilers, stills, and retorts, in the arts. In none of the above cases is an excessive degree of heat produced. But in the various furnaces so extensively used in the arts, very high degrees of heat result. To imitate these furnaces on a small scale for

experimental purposes, the blow-pipe is used in the laboratory.

22. The blow pipe is a small, bent tube, used to produce a fine jet of air, by means of which a flame is blown aside so as to concentrate its heat in a small space.

The best form of blowpipe, as represented in figure 1, consists of five parts. The mouth-piece, a, is of horn; the main tube, b, air-chamber, c, and main jet, d, are of brass or German silver, while the jet proper, e, is of platinum. This latter is represented in full size in a section below d, in the figure. The metallic pieces fit into one another with gentle friction, and may be taken apart; only the mouth-piece, a, is firmly attached with sealing wax to the tube, b.

The hole in the platinum jet is very fine. By proper care it never gets clogged; but, if it should get stopped in the hands of the beginner, the jet should be given to the teacher to be burnt out.* Never touch anything with the platinum jet, except the flame.

23. It is not very difficult to learn to blow if the following directions are carefully obeyed:

Firmly close your lips, distend the cheeks as widely as possible, and breathe slowly, regularly, and deeply through the nostrils alone — always keeping the cheeks fully distended during inhalation as well as during exhalation.

When you can do this for several minutes at a time, grasp the blow-pipe tube firmly with the right hand and press the mouth-piece against your lips. Support the tube on the thumb, third and fourth fingers, while the first and second fingers press the tube against the former just below the ring, f, on the tube. Thus the tube will be held firm as by a vise, and without special effort. See figure 2.

Bring the jet almost into the flame of a candle,† or

*It must never be drilled out.

†The wick of which has been bent aside in the direction of the jet.

alcohol lamp; you will then see it blown aside, as shown in figure 3. Continue to keep this blow-pipe flame steady, firm, and of the shape of a sharp cone. The flame must be kept as steady as if it were a solid body. Hold, by means of your left hand, a piece of iron wire (about one fourth of a millimeter thick) in the luminous point, b, of the blow-pipe flame. You will thus be able to see whether your blow-pipe flame is steady or flickering. Practice this experiment until you can keep the flame steady, at least during one minute.

The iron wire then will fuse, and burn often with scintillations; thus proving that the heat in the point of the blow-pipe flame is very intense.

24. By close inspection you will notice that the most luminous point, b, of the blow-pipe flame is really but the vertex of a hollow luminous cone, indicated by the shaded portion in figure 3. This point of greatest heat is also termed the fusing point or fusing region of the blow-pipe flame.

This bright, luminous cone is surrounded by a faint hollow cone of light, c, termed the outer flame of the blow-pipe. Inside of the bright hollow cone is the inner flame, d, of the blow-pipe.

These three regions of the blow-pipe flame have very different properties; hence the great importance of learning to keep the flame perfectly steady, so that only one of these regions acts upon the object. The abbreviations, o-fl. and i-fl. are often used to denote respectively the outer, c, and inner, d, blow-pipe flame.

25. On the smooth surface of a piece of charcoal† a small piece of lead — about one or two centigrams — is placed, as indicated in figure 4. Heated in the outer flame the lead fuses, partly volatilizes and burns,

†By means of a saw the charcoal is cut into blocks about 5 cm. wide, 10 cm. long and 2 cm. thick. The surface to be used is smoothed with a knife—over a tin box, to receive the dust. Be careful to keep your fingers clean.

covering the charcoal with a well defined, elliptical incrustation of a yellowish color. Perfect definition of this incrustation is a good test for perfect steadiness of the flame.

If you, thereafter, direct the inner flame upon any part of the incrustation, you will in a few instants convert that part of the incrustation into minute globules of metallic lead.

From this it appears that the i-fl. and o-fl. have opposite properties. Since the inner flame reduces the incrustations again to metallic lead, this part of the flame is often called the *reducing flame*. The outer flame, then, is termed the *oxidizing flame*.

26. Besides the charcoal-support here spoken of, we use platinum and glass-tube supports for substances to be heated in the blowpipe flame.

The platinum supports are the foil, the strip, and the wire. The platinum foil is a triangular piece of thin sheet platinum, about 1.5 cm. wide at the base, and 3 cm. long. For use, its vertex is held by a pair of steel tweezers,* or by inserting the vertex in a partly split-up match.

The platinum strip is cut from the same sheet platinum, and is about one mm. wide, three or five cm. long. It is held in the same manner as the foil.

The platinum wire is about half a millimeter thick and as long as the strip. One end of this wire is bent into a circular loop of about two mm. diameter, by twisting the wire around the platinum jet of the blowpipe.

27. The platinum foil is used for fusion and fluxing, being heated from below. The platinum strip is used for flame-colorations; the wire-loop for borax

*A small ring sliding along the tweezers keeps these shut so as to hold the foil firmly without special effort on the part of the student.

b e a d s. These different applications may be exhibited by the teacher before the class.

We shall, in the following, return more fully to this subject. For practice the student may simply heat the platinum as indicated: the foil from below, the strip at the fusing point, and the loop at the same point, but in such a manner that the flame passes through the loop at right angles to the plane of the same.

When these platinum pieces are first inserted into the fusing point of the flame they usually tinge the outer flame yellow. After some heating this color disappears, the outer flame becoming colorless. If you now touch the cooled strip with the so-called carefully cleaned finger, you will see the yellow color reappear upon re-heating the strip—thus proving that the carefully cleaned fingers contain something (salt) which tinges the flames.

This fact also shows the necessity of most careful cleaning* of the platinum wire.

Certain substances fusing readily together with platinum, it is important that the student should use the platinum only when expressly directed, in order to prevent the loss of this expensive metal.

28. The glass support for blow-pipe use consists in a narrow (3 mm. wide) glass tube, 5 cm. long, either closed at one end or open at both ends. In the former case (closed tube) heat alone can act upon the substance in the tube, the air being practically excluded as well as in a covered crucible. In the open tube a current of air necessarily passes along the tube, especially if the latter is held obliquely.

*This is accomplished by first fusing some sodium bisulphate on the platinum, then dissolving the fused mass with water, assisted by gentle friction, if need be,—followed by thorough washing and rinsing with water. Potassium bisulphate answers equally well.

The platinum strip and foil should also be kept smooth. To smoothen the foil or strip, hold them on a clean piece of glass, and repeatedly push the nail of a finger along the platinum in one direction only.

For the purpose of practice, a minute fragment (one or two cgr.) of pyrite may be heated in each of these tubes, and the results noted.

29. To succeed well with the blow-pipe, it is not sufficient to be able to produce a steady blow-pipe flame, and to apply constantly that region which is to be used; it is equally essential to take but a minute quantity of the substance to be acted upon. One centigram will in most cases prove quite sufficient. The test object should hardly ever measure more than a millimeter in any direction.

30. It will have been observed that precisely the same modes of heating here described are in constant use on a large scale in the arts. In these experiments only minute quantities being used—but in the arts the same operations often are performed on tons at a time.

Now it is true that the properties of a substance do not depend upon the absolute amount of the substance. See *Elements of Physics*, article 111. But at the same time the use of minute quantities in experimentation makes extreme care and cleanliness absolutely imperative, if the properties are to be distinctly and unmistakably recognized by the student.

II. RADIATION AND CONDUCTION.

31. The simple apparatus described in article 3, constitutes a thermometer, if it is provided with a centimeter scale;* for the higher the column of water in the tube, the greater the degree of heat. We shall make use of this exceedingly simple thermometer to demonstrate the law of cooling, and the principal facts in regard to radiation and conduction.

*A strip of card paper one centimeter wide, divided into centimeters and halves, attached to the tube by a few loops of thread and some sealing wax to keep it in place, will answer well enough.

The height of the column of water expressed by the number on the scale is called the temperature, or degree of heat of the water in the thermometer.

32. If the thermometer is heated on the water bath and thereafter exposed to the air in the room, the temperature of the thermometer will be observed to sink—first rapidly, then more slowly. The thermometer cools, losing part of its heat to the surroundings. The air in immediate contact with the thermometer becomes warmed and, expanding thereby (see 3), ascends, yielding its place to other portions of air, which in the same manner become warmed and are thereby removed; this diffusion of the heat of the thermometer is called convection. But the greater part of the heat of the thermometer is radiated in all directions.

33. The velocity, v , of cooling is directly proportional to the excess, e , of temperature of the cooling body over the surrounding; or, if c is a constant quantity, this law of cooling may be expressed by

$$v = c.e.$$

To demonstrate this law, first determine the temperature, t , of the surrounding by placing the thermometer in the position where it afterward is to cool, and keeping the thermometer in this place until it is stationary (neither sinks nor rises); read the temperature, t , now indicated. Then heat the thermometer on the water bath, by placing it on the watch glass so as to prevent its getting moist. Now remove it to the place occupied before, and accurately observe the time at which the sinking column passes the successive (half and full) divisions on the scale. This can be best done by two students working together, student A counting aloud the beats of a second pendulum (Elements of Physics, 39), the other student, B, observing the sinking column. Student B has on a slip of paper, entered one below the other, the divisions of the

scale above t ; while A counts aloud, B enters the number, n , called by A when the column exactly passes a given division, h , on his paper at the corresponding place.

Then the observations are entered in the journal of experiments in the following form:—

No.	||	h	|	n	||	i	|	v	|	e	||	$\frac{v}{e}$
-----	--	---	--	---	--	---	--	---	--	---	--	---------------

The first column gives the number of the observation made, the second the division or height, h , of the column at the number, n , seconds entered in the third column. In the fourth column the interval, i , seconds is recorded, expressing the time (in seconds) required to sink one (or one-half) division (cm). Hence the velocity, v , of cooling is

$$v = \frac{1}{i}$$

that is, the number of divisions which the column sinks in one second.

By subtracting the temperature, t , of the surroundings from each, h , we obtain the excess, e , in temperature of the thermometer over the surrounding, $e = h - t$. By finally dividing each, v by e , you obtain values in the last column not differing much* from one another. The mean of all these values you call c .

The law of cooling was first demonstrated by Newton.

34. If the cooling thermometer is placed upon a piece of iron or other metal, the velocity of cooling will increase very much; if it is packed in cotton contained in a paper box, the velocity of cooling will be diminished.

By such experiments it can readily be proved, that metals are good conductors of heat, while woolen cloth, hair, and cotton are very poor conductors. Wood is also a rather poor conductor; stone a better con-

*It is best only to use the values e , which are at least from 5 to 10 cm.

ductor than wood, but very much less a conductor than the metals.

Among the metals, silver and copper are found to be the best conductors for heat. Iron, lead, and especially platinum, are much less perfect conductors. The low conductivity of platinum contributes very much to make it a good support in blow-pipe experiments.

35. If such a thermometer has one portion of its side wall of bright glass, another portion painted with dull lampblack, a third coated with gold-leaf; if it furthermore during the cooling is packed with cotton in a paper box, one side of which has a circular opening somewhat less than the above coverings; then it will be found that the velocity of cooling is *l e a s t* when the gilt side radiates, greatest when the lampblack radiates, and intermediate for the glass.

These observations prove, that lampblack is the best radiator, metallic gold the poorest radiator, while glass is intermediate.

In a like manner the radiating power of other substances might be determined.

36. The facts and laws here demonstrated are of very general application in common life and in the arts. The student should point out a number of such applications.

III. THERMOMETER AND CALORIMETER.

37. No two thermometers, such as described in article 31, will indicate the same number on their scale, although put in the same place. They are, therefore, unfit for general use. Besides they are not very susceptible to small changes in temperature.

38. The thermometer now in general use consists of a stout glass tube, 5 mm. external diameter, with a very narrow flat* hole, figure 5. A cylindrical bulb of com-

*The hole is flat in order that the mercury filling it may be visible although but of a minute volume. The thread or rather ribbon of mercury filling a good thermometer tube can hardly be seen edgewise, although from the front it is easily observed.

paratively thin walls, but of an external diameter not greater than that of the tube, has been blown on one end of the tube. The tube and bulb are now completely filled with mercury at a high temperature, when the free end of the tube is closed by fusion. Upon cooling, the mercury column recedes toward the bulb, leaving a vacuum above it. (Elements of Physics, 129.)

If the bulb is inserted in a vessel containing small pieces of ice, the mercury column will first sink and then remain stationary. The point on the tube at which the mercury then remains in melting ice, is marked zero, and termed the freezing point of water.

Thereafter the thermometer is placed in water, and this by means of heat brought to boiling. The mercury rises with the heating of the water, but remains stationary again while the water boils. The point at which the mercury stands fixed in boiling water is marked 100, and called the boiling point.*

The distance between 0 and 100 is divided into 100 equal parts called degrees Centigrade or Celsius; the division is carried on above and below, thus giving a scale reaching from 30 degrees below zero to 200 or 300 degrees above zero. Degrees below the freezing point are usually called negative, and preceded by the sign — minus.

39. Mercury solidifies at about -40° , so that the mercury thermometer cannot be used for the determination of low degrees of heat. For this purpose other thermometers, containing alcohol (usually tinged red to distinguish it from the glass) are used.

Mercury boils at about 325° . Hence for the determination of high temperatures air thermometers are required, i. e., thermometers containing air instead of mer-

*In a water bath, the temperature, therefore, never can exceed 100° . See article 19

cury. But since air is very much affected by pressure, the air thermometer requires intricate calculations on the influence of the varying pressure of the atmosphere.

Two other thermometer scales are much used in the arts. Reaumur's scale marks the freezing point 0° , the boiling point 80° . On Fahrenheit's scale the freezing point is marked 32° , the boiling point 212° . These scales are, if necessary, distinguished by adding the initial of the name of the inventor to the number of degrees.

Thus, $50^{\circ}\text{C} = 40^{\circ}\text{R} = 122^{\circ}\text{F}$.

In the United States and in Great Britain the Fahrenheit scale is in general use in the arts; on the continent of Europe, Reaumur's scale prevails. In science, the Centigrade or Celsius scale is very generally used. It will be used exclusively in this work.

40. By performing accurate determinations of volume at different accurately determined temperatures, the amount of expansion (see 3) has been determined. It has been found that one cubic centimeter of the following substances taken at 0° expands by heating to 100° to the values given below:

Air, 1.366.	Lead, 1.0084.
Water, 1.043.	Silver, 1.0057.
Mercury, 1.018.	Copper, 1.0051.
Glass, 1.003.	Gold, 1.0045.
Steel, 1.0036.	Iron, 1.0036.
Platinum, 1.0025.	

If we except the expansion of air, these values of the expansion from 0° to 100° are so small, that the methods by which these quantities are determined cannot be studied in the elements, but must be deferred to the course in principles of physical science.

Here we shall add the curious fact that certain bodies contract, while being heated, at certain temperatures. Thus water contracts from 1.0000 to 0.9999 while heated from 0° to 4° . It is, therefore, one ten-thousandth more

dense at 4° than at 0° . Above 4° water expands continually while heated.

41. With a good mercury thermometer the experiment on cooling (33) may be repeated.* The thermometer may be inserted in a flask containing a known amount of water, or of mercury; the amount of liquid may be changed, and the experiment may be otherwise modified.

Another even more important experiment for students, is the verification of the fixed points (0 and 100) on the thermometer scale.

The student should also be required to observe the temperature of the air at given hours of the day during a week.

Great care should always be taken to read the temperature correctly and without disturbing the thermometer by the heat of the body of the observer. In more refined experiments the thermometer is therefore read from a distance by means of a telescope.

42. The thermometer merely measures the degree of heat, not the amount of heat. To understand this important point, suppose you pour 10 cc. water into a small flask and 100 cc. of the same water into a beaker; suppose the water to have the temperature of the room, 16° . A thermometer inserted into either vessel will therefore indicate the same degree of temperature.

If, now, both vessels are heated on the water bath, then after some time the water in both will have reached the temperature of say 30. Again the thermometer indicates then the same temperature in the beaker and in the flask; the temperature of the water in each was raised 14 degrees, namely from 16 to 30 degrees.

But it is evident, that it requires more of heat to raise 100 grams of water 14 degrees, than to raise 10 grams

*A good thermometer cannot be had except at a cost of several dollars. Hence be very careful while handling thermometers.

of water this same number of degrees. The amount of heat imparted to the 100 cc. water in the beaker is evidently 10 times as great as the amount of heat imparted to the 10 cc. water in the flask.

Hence it is evident that the amount of heat imparted to a body or taken from a body does not merely depend upon the change in temperature of the body, but also the weight of the body and even the specific nature of the body. Heat, then, must be measured in its own unit, the calory.

43. A calory is the amount of heat required to raise the temperature of one gram of water, one degree centigrade—from 0° to 1° . A kilocalory is 1000 calories, or the heat required to raise the temperature of one kilogram one degree.

The term calory is used for the sake of brevity instead of the phrase unit of amount of heat. In practice the word calory is often abbreviated thus: cal.

44. A calorimeter is an apparatus for measuring the amount of heat in calories.

In its simplest form the calorimeter consists of a light flask (about 200 cc. capacity) with a light, sensitive thermometer, and a known weight, w , grams of water. If the temperature of this water rises t° —indicated by the thermometer— w times t calories = $w \cdot t$ cal. have been imparted to the water.

For example, to 100 grams of water of 16° in the calorimeter add by a 10 cc. pipette 10 grams of water of 38° ; shake, and read the temperature of the mixture. You will find it 18° .

Hence the 100 gr. in the calorimeter rose 2° , requiring 200 calories. The 10 gr. added lost 20° in temperature, or gave off $10 \times 20 = 200$ calories, equal to the heat imparted to the water in the calorimeter.

In all cases the amount of heat (in calories) imparted to the calorimeter, is equal to the amount of heat lost by the heating body.

For this experiment (and also for 45), it is best to have a large amount of water of both temperatures at hand in large vessels, so that the temperature does not readily change. Then one thermometer in the calorimeter is sufficient.*

45. But it requires also a certain amount, c , of heat to change the temperature of the calorimeter (flask and thermometer) one degree. This value, c , is termed the water-value of the calorimeter.

To determine the same, add a known weight, W , grams of water to the w grams of water in the calorimeter. Very carefully observe the temperature of the calorimeter-water, w , the added water, W , and the temperature of the mixture. You will thus find how many degrees, T , the added water was cooled, and how many degrees, t , the calorimeter was heated.

To heat w grams t degrees requires $w \cdot t$ calories. To heat the calorimeter of water-value c grams the same number of degrees requires $c \cdot t$ cal. additional. Hence the calorimeter received $w t + c t$ calories.

The W grams of water added, lost T degrees, or $W T$ cal. Hence we have

$$w t + c t = W T$$

From this follows

$$c = \frac{T}{t} \cdot W - w$$

as the number of grams of water equivalent to the calorimeter (flask and thermometer).

For actual practice it is well to make W and w

*Either transfer by pipette of known volume, or weigh after the reading of the thermometer has been taken.

nearly equal, and to have the hot water only 10 or at most 15 degrees warmer than the cold water. See remarks at close of 44.

46. Calorimeter with chamber. If the matter experimented upon cannot be mixed with the water in the calorimeter, this apparatus is provided with a chamber wherein the body is placed while giving off its heat.

Thus to determine the amount of heat produced by the combustion of charcoal the combustible is burnt in a metallic chamber surrounded by the water of a sufficiently large calorimeter. The amount of water, w , in the calorimeter, and the water value, c , of the calorimeter are known as well as the change, t , in temperature produced by the combustion of a known weight (n grammes) of charcoal. Then if n grams produce $wt + ct$ cal., one gram of charcoal produces by its combustion

$$\frac{wt + ct}{n} \text{ cal.}$$

47. In this manner Favre and Silbermann found that one gramme of the following substances produces by complete combustion the number of calories stated opposite its name:

GASES AND LIQUIDS.	SOLIDS.
Hydrogen.....34,460 cal.	Anthracite..... 8,460 cal.
Marsh gas.....13,060 "	Charcoal.....8,080 "
Olefiant gas.....11,860 "	Coal, good.....8,000 "
Oil of turpentine..10,850 "	Tallow .....8,000 "
Olive oil..... 9,860 "	Coke .....8,000 "
Ether 9,030 "	Wood, dry .....4,025 "
Alcohol 8,960 "	" moist ...3,100 "
Wood spirits 5,300 "	Phosphorus ....5,750 "
	Sulphur 2,260 "
	Iron.....1,580 "

Common illuminating gas consists essentially of olefiant and marsh gas, and produces about 12,000 cal. per gram by combustion.

48. The SPECIFIC HEAT, s , of any substance is the number of calories required to heat ONE gram of the substance ONE degree centigrade. According to 43 the specific heat of water is therefore one. For most other substances the specific heat is much less than one, especially for the heavy metals, like gold, mercury and lead.

49. To produce a change of t degrees in the temperature of a substance of specific heat, s and weight, w , requires, therefore, $s \cdot w \cdot t$ calories.

50. Accordingly the specific heat of a substance not affected by water may be determined by immersing a known weight of the substance, heated to a known temperature, into the water of a calorimeter, and carefully observing the resulting temperature.

If, then, the water in the calorimeter, together with the water value of the calorimeter, be W grams, the change in temperature in the calorimeter be T , the calorimeter will have received $W \cdot T$ calories.

If at the same time the w grams of the substance lost t degrees in temperature, the substance gave of $s \cdot w \cdot t$ calories to the calorimeter; see 49.

Hence $W \cdot T = s \cdot w \cdot t$

from which the specific heat s of the substance

$$s = \frac{W \cdot T}{w \cdot t}$$

51. By means of a lead weight or ball of $w = 500$ grams, heated in the water of the water bath to about 90° , then immersed into a beaker-calorimeter containing about 300 grams of water of common temperature, the specific heat of lead may be determined by the student. About one hundred grams of glass fragments, heated in a beaker on the water bath, will also give a good result.

52. Careful experiments of this kind have given for

the following bodies the specific heat given opposite the names :

MINERALS.		METALS.	
Marble.....	0.216 cal.	Lead.....	0.031 cal.
Calcite.....	0.205 "	Platinum.....	0.032 "
Siderite.....	0.182 "	Gold.....	0.032 "
Hematite.....	0.164 "	Mercury.....	0.033 "
Pyrite.....	0.130 "	Tin.....	0.056 "
Blende.....	0.115 "	Silver.....	0.057 "
Barite.....	0.109 "	Copper.....	0.096 "
Galenite.....	0.053 "	Brass.....	0.094 "
<hr/>		Zinc.....	0.096 "
Glass.....	0.198 "	Iron.....	0.114 "
Water.....	1.000 "	<hr/>	
Air.....	0.237 "	Phosphorus.....	0.189 "
		Sulphur.....	0.203 "
		Charcoal.....	0.241 "

Accordingly it requires only 33 calories to heat 100 grams of mercury 10 degrees, while it requires 1000 calories to heat an equal weight of water the same number of degrees.

IV. FUSING AND BOILING.

53. The conversion of a solid into a liquid by means of heat is termed *f u s i o n* (see 4, and also Elements of Physics, 113 and 151). But not all substances are *f u s i b l e*; some are *volatized* or even *decomposed* (see 5) by heat, without fusing. The change from liquid to solid by cooling is termed *s o l i d i f i c a t i o n*.

54. *V o l a t i l i z a t i o n* is the conversion of a liquid into vapor or gas by means of heat. But not all liquids are *volatile*, some *decomposing* (see 5) by heat without volatilization.

Water, kerosene, and alcohol are *volatile liquids*; sweet oil is a *non-volatile liquid*. Liquids, which are *non-volatile* are, also, at times, called *fixed liquids*.

By cooling, the vapor formed is *c o n d e n s e d* again to a liquid. This change of aggregation is also often called *l i q u e f a c t i o n*.*

*The water on the surface of the earth shows all these changes in aggregation on a grand scale (see Cosmos). It *evaporates*, and as *s t e a m* forms part of the at-

55. Volatization takes place mainly at the surface of the liquid; hence it is accelerated in wide and shallow vessels. If a liquid is volatilized intentionally the process is also called *evaporation*. This operation is usually performed on the water bath.

If the liquids yield combustible or obnoxious vapors, evaporation has to be performed with great care in apparatus specially prepared for this purpose.

56. If a volatile liquid such as water is heated in a flask on a sand bath, volatilization at the surface will soon be accompanied by the formation of small bubbles of vapor at the bottom and walls of the flask. These bubbles will ascend, and diminish in size, producing the well-known *simmering* sound. After some further heating, the bubbles formed will no longer condense, but rise through the liquid, increasing in size as they rise to the surface, where they burst. The liquid will at the same time be put into a violent commotion by these bubbles. In this state the liquid is said to *boil*. Hence:

A liquid *BOILS* when vapor is formed throughout its entire mass in bubbles, which increase in size as they rise through the liquid, thereby commoting the liquid.

57. If the vessel be completely closed, the liquid will not boil; vapor will continue to form until the pressure thereof opens the vessel by *explosion*.

It is not even necessary that the vessel should be completely closed; if the opening be insufficient to permit the vapor to escape as fast as formed, explosions may also

mosphere at all times. Upon cooling, a portion of this steam condenses, and becomes visible as clouds, fogs or dews. Rain is condensed vapor descending from higher parts of the air.

Hail, snow, frost, and ice result when the temperature sinks below the freezing point.

occur upon continued heating. Examples: accidental explosions of steam boilers.

58. In the process of distillation, boiling and liquefaction take place at the same time in different portions of the apparatus. A distilling apparatus, therefore, always consists of two parts, the flask or retort, wherein the liquid to be distilled is boiled, and the condenser, wherein the vapor formed is liquefied again.

The heat imparted to the liquid in the flask, to convert the liquid into vapor, has to be removed from the vapor in the condenser in order to re-convert the vapor into liquid. This is usually accomplished by passing a slow current of cold water along the tube wherein the vapor escapes from the flask.

If the volatilized substance condenses to the solid form, this process is no longer called distillation, but sublimation.

59. A vertical section of a simple distilling apparatus for students' use is represented in figure 6. The glass flask, A, (from 50 to 100 cc. capacity) is heated on the water or sand bath. The condenser consists of a wide glass tube, B C, which by a rubber or cork stopper is fitted into the flask. The tube, B C, passes first vertically upwards, and thereafter slopes gently down, its lower end being inserted into or placed above* the receiver, D. A tin tube, about three times as wide as B C, encloses nearly two-thirds of this tube, which is fitted into the tin tube by corks, K K. Narrow glass tubes are fitted by means of corks to the tin tube at E and at F. The lower glass tube, F, is by means of a rubber-hose siphon connected with a flask, G, with water, while the upper glass tube, E, is by means of another rubber tube connected with the flask H. To regulate the flow of water, an ad-

*Students should not distil any dangerous liquids: at least no liquid more volatile than alcohol. Otherwise very special precautions are to be taken, which it is superfluous here to detail.

justable spring clamp of some kind should be put upon the rubber tube from G.

The condenser may be further simplified, but it is not advisable to do so for actual and frequent use in the school laboratory.

The flow of the condensing water should be so regulated that the water collecting in H is only 10 or 15 degrees above the temperature of the room. A few pieces of ice thrown into G increases the effectiveness of the condenser very much.

60. The operation of distillation is of the utmost importance, both in the arts and in science; for by distillation we can readily separate the more volatile substances from the less volatile materials.

Thus we obtain distilled water, free from any of the non-volatile impurities of common well and cistern water by distilling the latter—the impurities remaining in the still or flask. So alcohol, volatile oils, and many acids are manufactured.

By placing petals of roses in the water of the flask, we obtain rose-water, by distillation, possessing the characteristic odor of the rose. Hence, the odor of the rose is due to some volatile substance.

If the plant contains enough of the volatile substance the latter often collects on the water in the receiver, as in the case of the light volatile oils.*

Examples for students' laboratory practice are readily selected from the preceding.

*To increase the interest in the operation of distillation, the student may add from one to five grammes of some of the following crushed vegetable materials to 25 to 50 cc. water to be distilled. He will then in all cases have enough of the volatile oil distilled over, to recognize it. If the oil is lighter than water it will float on the surface of the water in the receiver; if it is heavier, it will be found at the bottom. Hence we add the specific gravity, G, of the oil to guide the student.

It is also important to notice that the boiling point, T, of many volatile oils is higher than that of water; still, in the presence of much steam, these oils are carried over with the latter.

61. In case the flask contains a mixture of two liquids of different volatility, these liquids may be partially separated by fractional distillation. The first portion (fraction) passing into the receiver contains mainly the most volatile of the two liquids. The receiver is then changed to receive another fraction of the distillate, which already will contain more of the less volatile substance. In this manner, by several changes of the receiver, small fractions of the distillate are separately collected, each succeeding fraction being less volatile than the preceding one.

Example: Mixture of alcohol and water, or alcohol and glycerine. Determine the specific gravity of the mixture and of each fraction.

62. Having now studied the different changes of aggregation in a more general manner, we are prepared to understand and to demonstrate the laws governing these changes.

The laws of fusion are:

1. A fusible body fuses at a fixed degree of temperature, termed the fusing point.

2. It requires a fixed amount of heat to convert one gram of the solid at the fusing point into a liquid of the same temperature; this amount of heat is the latent heat of fusion of that solid.

The part of the plant used is indicated; also the common and official name of the plants, as well as the yield of oil in centigrams for one gram of the part of plant used:—

COMMON.	OFFICIAL.	PART.	W.	G.	T	NOTE.
1. Black mustard.	<i>Sinapis nigra.</i>	seed.	5	—	—	very pungent.
2. Bitter almond.	<i>Amygd. amara.</i>	kernels.—	—	—	—	poisonous.
3. Clove cinnamon.	<i>Persea caryophyll.</i>	bark.	—	—	—	dark brown.
4. Peppermint.	<i>Mentha piperita.</i>	herb.	1	0.9	185°	—
5. German chamomile.	<i>Matricaria chamomilla.</i>	flower	7	0.95	—	blue.
6. Cloves.	<i>Coryoph. aromat.</i>	flower buds.	5	1.04	243°	—
7. Black pepper	<i>Piper nigra.</i>	fruit	2	0.9	—	—

The oil is named after the plant from which it is obtained. Thus "mustard oil," "oil of bitter almonds," etc.

Of course, only some one of these distillations should be performed by each student.

The laws of ebullition exactly correspond to the preceding, namely:—

1. In an open vessel a liquid boils at a fixed degree of temperature, called the boiling point of the liquid.

2. It requires a fixed amount of heat to convert one gram of the liquid at the boiling point into vapor (gas, steam) of the same temperature. This amount of heat is called the latent heat of vaporization of that liquid.

It is apparent that the laws of fusion and ebullition may be expressed in one law as follows:

If by heat the state of aggregation of a substance changes, this change takes place at a FIXED DEGREE of temperature, and consumes (or produces) a FIXED AMOUNT of heat for each gram of the given substance.

It is hardly necessary to state that the heat required to change the solid into liquid is again reproduced when this liquid changes to solid. So also the heat consumed in vaporization is again produced in liquefaction.

We shall now detail the experiments which quantitatively demonstrate the above laws.

63. A portion of a readily fusible solid, in small fragments, is heated in a flask or dish on the sand bath. A sensitive thermometer, surrounded by the solid, is carefully read at the end of each one or two minutes. The results recorded in the journal thus:—

No.	Time.	Temperature.	Increase.	Remarks.
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In the last column the appearance of the substance is recorded.

It will then be found that the temperature rises quite uniformly at first; that after a while the rise or increase

in each interval of time becomes smaller; that finally, when the substance commences to melt, the temperature ceases to rise.

These observations should be graphically represented, the time as abscissæ, the corresponding temperatures as ordinates. (Compare Elements of Physics, 74). The curve drawn through the extremities of the ordinates then will be found to rise gradually at first, to remain horizontal while the substance melts, and to slowly ascend again after all of the substance has been melted.

Ice is the most convenient example. Stearine, bee's wax, sulphur, and fusible alloys of bismuth, lead and tin (proportions, 2 : 1 : 1) may also be used by the student.

64. In a like manner observe the gradual heating and final ebullition of a liquid; water or alcohol are most suitable for students.

In the case of water the flask may be open; but in case alcohol is used, it should be heated in a distilling apparatus (59) of sufficient size that a thermometer can be inserted air tight through the cork. The thermometer should reach to within about a half centimeter of the bottom of the flask.

Record the experiments, represent them by co-ordinates precisely as directed above, 63.

65. But few common substances can be changed within moderate temperatures from solids to vapors; and even these few should not be experimented with by the student.

The following table gives the boiling and fusing point of some of these substances:

	FUSING POINT.	BOILING POINT.
Mercury.....	—39°.....	350°.
Bromine	—7°.....	63°.
Water	0°.....	100°.
Phosphorus.....	44°.....	280°.
Iodine	107°.....	175°.
Sulphur	115°.....	408°.

The rise in temperature observed in heating separately a small quantity of ice and of iodine is represented by co-ordinates (see 63) in figure 7. The full line corresponds to water, the dotted line to iodine.

From the above it will appear that the fusing or boiling point of any substance is a most important specific property of the same, which ought in all cases to be determined, to form part of the description of the substance. Compare *El. Phys.*, 214.

66. The latent heat of fusion and of vaporization is indicated in the diagrams of 63, 64, and 65 by the horizontal position of the curve. Since during the changes of state the temperature fails to rise, although heat is continually applied, it follows that heat is required to effect this change.

To determine the precise amount of latent heat requires careful experimentation with the calorimeter. Here it must be sufficient to determine the latent heat of fusion for ice and the latent heat of vaporization for water.

67. The latent heat of water is the number of calories required to convert one gram of ice of 0° into water of 0° . (Compare 62.)

To the water in the calorimeter add from five to ten grams of ice in small pieces (dried between blotting paper) for each 100 cc. water in the calorimeter. Carefully ascertain the changes in temperature.

If the weight of the water (together with water-value of calorimeter, see 45) is W , its change in temperature is T , then $W T$ calories have been removed from the calorimeter.

If w grammes of ice of 0° were taken and fused, the fusion required $w \cdot l$ calories. The water of 0° resulting was warmed to t° , the final temperature in the calorimeter, this requires $w \cdot t$ calories. Hence

$$W \cdot T = w \cdot l + w \cdot t$$

or the latent heat of water

$$l = \frac{W}{w} \cdot T - t$$

Careful experiments have given $l = 79.25$ cal.

68. The latent heat of steam is the number of calories required to convert one gram of water of 100° into steam of the same temperature. (Compare 62.)

Distill about 10 cc. water in the usual manner, but observe carefully the temperature of the cooling water, and the temperature of the water having served for cooling; suppose it has been heated T degrees. Also determine the weight of the cooling water actually used — W grams.

Thus by the condensation of the w grams of distilled water obtained, $W \cdot T$ calories have been imparted to the cooling water.

If the latent heat of steam is l , the liquefaction of w grammes of steam of 100° to water of 100° yields $w l$ calories. This water is furthermore cooled t degrees, determined by observing the temperature of the distilled water and subtracting this temperature from 100° . By this cooling an additional amount of $w t$ calories is given to the condensing water. Hence

$$W \cdot T = w \cdot t + w l$$

from which

$$l = \frac{W}{w} \cdot T - t$$

About 1,000 grams of cooling water should be used for each 10 grams of water distilled.

The most careful experiments have given $l = 537$.

69. The following very striking and highly important results have been established by such experiments. (67, 68):—

1 gr. ice of $0^\circ + 79.25$ cal. = 1 gr. water of 0° .
 1 gr. water of $0^\circ + 100$ cal. = 1 gr. water of 100° .
 1 gr. water of $100^\circ + 537$ cal. = 1 gr. steam of 100° .
 Accordingly

1 gr. ice $0^\circ + 716.25$ cal. = 1 gr. steam of 100° .

and also, 1 gr. steam of 100° — 716.25 cal. = 1 gr. ice of 0° .

It will be seen that the mere change from solid to liquid requires for water as much heat as to raise the temperature of water of common temperature to the boiling point. To change boiling water to steam requires nearly seven times as much heat!

Again, one gram of steam condensed to water of 20° yields 617 calories, or as much of heat as 617 grams of water cooled one degree!

Upon these facts rest the applicability of steam for heating purposes and the enormous consumption of fuel* for the production of steam.

70. A multitude of common phenomena can be explained by the laws demonstrated in the preceding. The action of freezing mixtures (Elements of Physics, 113, note); the cooling effect of any evaporating liquid; the

*The following practical facts will prove of interest:—

The proper temperature of a room for occupation by man is 15° . Each full grown healthy person requires about 10 cubic meters fresh air per hour; and gives off (above the heat consumed in his perspiration) about 45 kilocalories (kgr. degrees) per hour. If now the air outside the room is t degrees below 15° , a number n persons in the room require

$$w' = 3n(t - 15)$$

kilocalories per hour, as you will readily calculate from the above data in connection with 52 and Elements of Physics, 33.

To compensate for the cooling effect (admission of cold air, etc.,) of the outer walls, requires

$$W'' = F \cdot t$$

kilocalories per hour, if the surface of the outer walls be F square meters (window surface counted twice).

Hence, a hall to hold n persons requires of heat per hour kilocalories;

$$W = w' \text{ plus } w'' = Ft \text{ plus } 3n(t - 15)$$

Since one kilogram steam on the average yields 550 kilocalories by condensation and cooling, this room will require $s = 0.00182$ w kgr. steam per hour, and 0.0012 w square meters of steam-pipe surface, if the room is to be heated by steam. To produce this amount of steam requires in practice about one-seventh of coal, or 0.00026 w kgr. coal per hour, and a heating surface in the steam boiler of 0.000125 times w square meters.

By means of these data (from Weisbach) you can readily solve the principal questions in regard to the heating of rooms and buildings by steam.

The area, V , (in square meters) of the opening of the ventilator, the height of which is h meters, should be

$$V = 22 \frac{n}{\sqrt{h \cdot t}}$$

to allow 10 cubic meters of fresh air per hour for each person. *

solidification of carbon bisulphide* by violently blowing upon a small portion contained in a watch glass—are a few characteristic instances to test the student's sagacity. The teacher may add other instances of a like nature. Also solve some practical problems on heating by steam, using the data given in the foot note to 69.

71. In the preceding the boiling liquid was supposed to be in an open vessel, hence under the common pressure of the atmosphere (76 cm., see *Elements of Physics*, 130). The laws of ebullition remain essentially the same if the pressure on the liquid changes; except that the boiling point rises and sinks with the pressure on the surface of the liquid.

Thus water does boil at 83° if the pressure on its surface is diminished to one-half (38 cm.); it boils already at 50° if the pressure is diminished to one-tenth (7.6 cm.), while it does not boil until heated till 144° if the pressure is four times as great as usual, (304 cm.).

72. The pressure, p , of vapors corresponding to any temperature, t , has been carefully determined for different liquids by experiments with the apparatus represented in figure 8.

In the strong boiler, B, the liquid is heated. The temperature of the liquid is determined by the thermometer, t , immersed in the mercury contained in a narrow iron tube. A strong tube, D, passes from the boiler to a closed cistern, C, with mercury. A vertical glass tube, A, open at both ends, passes through the cover of C into the mercury.

When the thermometer, t , in B, remains stationary, the level of the mercury in A measures the pressure, p , of the vapors corresponding to that temperature, t . In this manner the following results have been obtained, the pres-

*If the teacher wishes to perform this really striking experiment, he should bear in mind the great combustibility and the offensive odor of this substance. Exhibit the experiment immediately before dismissing the class.

sure being expressed in centimeters of mercury. (See Elements of Physics, 121):—

t	20°	0°	20°	40	60°	80	100
Mercury.		0.002	0.004	0.008	0.02	0.04	0.07
Water.	0.1	0.5	1.7	5.5	14.9	35.5	76.0
Alcohol.	0.3	1.3	4.5	13.4	35.1	81.3	169.5
Ether.	6.8	18.3	43.3	91.0	172.9	302.4	495.1

It will be noticed that the pressure increases at a much more rapid rate than the temperature. The same is apparent from the following table for steam of water above 100°. The pressure is given in atmospheres of 76 cm. mercury each. (Elements Physics, 130):—

Pressure.	1	2	2	4	5	6	7	8	9	10	15	20
temperature.	100.0	120.6	133.9	144.0	152.2	159.2	165.3	170.8	175.8	180.3	198.8	213.6
Rise for each new atmosphere.	20.6	13.3	10.1	8.2	7.0	6.1	5.5	5.0	4.5			

These values are represented in figure 9. The temperature as abscissæ (scale 50 degrees to the centimeter), the corresponding pressure as ordinates (2 atmospheres to the centimeter).

For these higher temperatures, t , (above 100°) the pressure, p , per square centimeter is nearly

$$p = \left(\frac{t}{100} \right)^4$$

kilograms. This formula gives for $t = 200^\circ$ a pressure of 16 kilograms; direct observation has given 5.89 kilograms.

CHAPTER II.

HEAT AND MECHANICAL WORK.

73. Very much of the mechanical work accomplished in civilized countries is performed by steam power. By the use of steam the population of these countries, in regard to absolute mechanical power and production, is virtually greatly increased. Besides, a comparatively larger percentage of the actual population, by this steam power, becomes released from muscular labor, and is permitted to cultivate their intellectual powers. Thus, the steam power is in every respect one of the principal pillars of modern civilization.

This is, however, not the place for an elaboration of these views; nor can we here give detailed descriptions of steam engines. In these elements of physical science, it would be improper to go beyond the fundamental principles upon which the application of steam power depends. Hence we shall say nothing about those parts of the steam engine, which serve to transmit the power to the various machines to be moved; we shall only refer to the two most essential parts of every steam motor, namely the boiler and the cylinder.

74. The combustion of fuel under the boiler converts the water in the boiler into steam.

To convert one gram of water of 0° into steam of 100° requires (see 68 and 69) 637 calories. If the steam is to be heated more, in order to possess a higher pressure (see 72), it requires about 0.3 calories more for each additional degree in temperature (Regnault). Since in common practice the water used is of a temperature of from

10° to 20°, we may say, that about 648 calories are sufficient to convert one gram of the water used, into steam commonly applied.

But 1 gram of good coal produces by complete combustion, 8,000 calories; hence, if completely utilized, one gram of good coal would convert $12\frac{1}{2}$ grams of water into steam under usual circumstances. In other words, 1 gram of water would require but 0.08 grams of good coal to be converted into steam.

Therefore, to convert S kilograms of water into steam would require only

$$C = 0.08 S$$

kilograms of good coal, if the same could be completely utilized.

In practice, much of the heat is wasted—some necessarily, in order to produce the draft in the chimney, etc. Hence, twice the above amount of coal is used, or in practice*

$$C = 0.16. S$$

The heating surface, F , of the boiler, B , required to produce, S , kilograms of steam per second is

$$F = 150. S \text{ square meters.}$$

75. The steam produced in the boiler passes through a wide tube, n , to the steam cylinder, C , figure 10. In this cylinder a piston, M , fits steam tight, and is pushed alternately up and down the cylinder, by the steam being admitted alternately at the bottom (through 2) and at the top (through 1) of the cylinder.† The piston-rod, r , is connected with the machinery to which the motion produced is to be communicated.

*Redtenbacher gives 0.15.

†The valve chest, ch , contains a hollow slide, m , the cavity of which communicates with the air or with the condenser. (See 76.) In the position of the slide shown in the figure, the piston is forced upwards, C communicating with n , and c with m ; hence the piston is forced down. When down, the slide is pushed down again, whereby the piston moves up as shown above. In this manner the steam is admitted alternately above and below the piston.

The details of construction vary exceedingly in different machines; they are described in special treatises on the steam engine. Here it must be sufficient to show how the nominal power of the engine can be calculated from the diameter, d , (centimeters) of the piston, the length s , of the stroke (in meters), the number, n , of strokes per second, and the pressure, p , in the cylinder (in kilograms per square centimeter). If the area of the piston is a square centimeters, the total pressure on the piston is $a.p$ kilograms.

Hence the mechanical work of each stroke is $s.a.p$ kilogrammeters. (See *El. of Phys.*, 84); and in each second (n strokes) the work will be $n.s.a.p$ kgr. M, or (according to *Elements of Physics*, 85)

$$N = \frac{n. s. a. p}{75}$$

horse power.

Since $a = \frac{\pi}{4} \cdot d^2$ (*Elements of Physics*, 48), the above number of horse powers is also very nearly

$$N = \frac{n. s. p. d^2}{100}$$

The pressure in the cylinder is about $\frac{3}{4}$ of the pressure in the boiler, which latter pressure is indicated by proper gauges.

76. While the steam is admitted to one side of the piston, the steam in the cylinder on the other side of the piston is permitted to escape through the slide, m , (fig. 10).

In High Pressure engines this steam escapes into the atmosphere; but in doing so it has to overcome the pressure of the atmosphere, thus reducing the effective pressure one unit. In order that such machines can work to advantage, the pressure of steam in their boiler

must therefore be rather high; it is usually about 6 or 7 atmospheres.

In Low Pressure engines, m connects with a condenser, that is, a large reservoir wherein cold water is constantly injected. The steam is thereby condensed, and on the corresponding side of the piston hardly any pressure is left. Such machines can therefore work even with one atmosphere pressure in the boiler, hence their name.

The principal advantage of the condenser consists in the recovery of some of the latent heat of the steam. The water, warmed thereby in the condenser, is pumped into the boiler, thus saving fuel. But the condenser makes the machine also more cumbrous, and cannot be used at all on locomobiles.

77. It is not necessary that steam be admitted to the cylinder during the entire stroke. After about one third of the stroke, when therefore the cylinder is $\frac{1}{3}$ filled with high pressure steam, the steam may be cut off from the boiler; the great pressure will continue to carry the piston on, while the steam back of it expands from $\frac{1}{3}$ cylinder till it fills the entire cylinder. Machines provided with such cut off are termed Expansion Machines. They save much steam, and also economize heat, because during expansion the steam partially liquefies in the cylinder; the latent heat thus resulting increases the effect of the steam remaining uncondensed under the piston.

High pressure engines are usually without condenser and without expansion; they require about one kilogram of steam per second for every 150 horsepower. Low pressure engines have usually both expansion and condenser; they work at times as many as 250 horsepower by one kilogram of steam per second.

78. In order to become acquainted with the relation of the various rules and laws here given, the student should solve the following problem:—

An express train is to be moved with a velocity of 15 meters per second (about 54 kilometers or 35 miles an hour) on a good railway, which for this velocity gives the coefficient of 0.01. (See Elements of Physics 102). The locomotive with tender weighs 20 tons (of 1,000 kgs each), the balance of the train weighs 80 tons.

Required to find how many horsepowers the locomotive must have ; how great the diameter of each of its two equal steam cylinders, if each piston is to make 2 strokes of 0.63 meters per second ; also, how much water and coal will be required per second and per hour. The locomotive has of course a high pressure engine without expansion and without condenser, using steam of from 6 to 7 atmospheres pressure.

Besides solving problems like the above, the students should visit good steam engines and carefully observe the same both while at rest and while in activity.

79. The steam engine constitutes a most striking demonstration of the fact that heat produces mechanical work. As shown in the preceding, hundreds of horsepower are performed by the heat resulting from combustion under the boiler of a single steam engine. Thus we may well ask, how much of mechanical work is produced by the expenditure of one kilocalory? How much can be produced!

Again, it is a matter of quite common observation, that mechanical work produces heat. The hammering of a piece of lead makes it warm; rubbing two pieces of wood produces fire; stopping a train by the brakes makes the sparks fly; and in the dressing of castings of iron by means of rapidly revolving wheels, the sparks form a continuous and beautiful shower. Hence the question also turns up, how many calories are produced by one dynamo?

80. R. Mayer of Heilbronn, in 1842, first solved both of these questions in an unmistakable manner; Joule

of Scotland, and C o l d i n g, of Denmark, demonstrated the results of Mayer experimentally. Already C a r n o t, of France, in 1824, showed that the mechanical work of the steam engine is intimately related to the heat expended; while R u m f o r d in Bavaria (but a native of the United States), already at the beginning of this century proved experimentally that the expenditure of a certain amount of mechanical work produced a certain amount of heat.

As the great result of numerous experimental researches performed in the most different manner by different experimenters, it appears that mechanical work and heat may be transformed one into the other according to the following simple law:—

One calory is equivalent to 425 dynamos; and inversely, one dynamo is equivalent to $\frac{1}{425} = 0.0024$ calories.

Hence one kilogram-degree can produce 425 kilogram-meters of mechanical work. The latter quantity is often termed the mechanical equivalent of heat.

As a necessary conclusion the mechanical theory of heat results, according to which heat is a vibratory motion of the particles.

81. The most accurate determinations of the mechanical equivalent of heat have been made by J o u l e, beginning as early as 1843, independent of other investigators.

He used a calorimeter, B, figure 11, containing a known amount of water, w, and of a known water, value, c; compare 45. In this calorimeter a paddle wheel (indicated by dotted lines in the figure) moves between four fixed metallic partitions, leaving but a little more space than required for the paddles to pass; hence, when the paddle wheel is revolved by rotation of its vertical axis, A, the water in the calorimeter is violently agitated (as in a churn).

The rotation of the paddle wheel is produced by the sinking of a known weight, W , attached to the axis in the manner shown by the figure.

Joule now carefully observes the temperature of the water before and after the sinking of the weight; thus he obtains the rise, t , in temperature produced by the motion. Hence the number of calories $(w + c) t$ produced is determined.

Knowing the weight, W , and the height, h , through which it descends, he has $W \cdot h$, the number of dynamos expended.

Hence if x , the number of dynamos required to produce one calory, we have

$$W \cdot h = x \cdot (w + c) t$$

where all quantities are directly observed, except x .

From his experiment, Joule found in 1849 the mean 772 foot pounds English, for one pound-degree, Fahrenheit; which corresponds to 425 kilogram-meters to one kilocalory, as above stated.

By other experiments it has been proved, that the expenditure of one calory again reproduces 425 dynomos. Hence heat and mechanical work are equivalent in the proportions stated in 80.

82. Accordingly, if any number, C , of kilocalories are completely converted into mechanical work, W (kilogram-meters), we have

$$W = 425 \cdot C \quad A.$$

Inversely, if any given amount, W , of work be completely converted into heat, C , we shall have

$$C = \frac{W}{425} = 0.0024 \cdot W \quad B.$$

By these formulæ, expressed in words in 80, we can always reduce work to heat* or heat to work.

*Heat is accordingly but work accomplished internally, in moving and disturbing the particles.

83. By these equations, demonstrated by experiment, (81), we may test the efficiency of the steam engine in the following manner :

One kilogram of good coal does produce 8,000 kilocalorie by combustion (see 47). Hence the combustion of one kilogram of good coal ought to produce $425 \times 8,000$, = 3,400,000 kilogram-meters of mechanical work. (See 82). Now, a horse power continued for one hour represents $75 \cdot 60 \cdot 60 = 270,000$ kilogram-meters of work. Hence the combustion of one kilogram of good coal per hour should produce $12\frac{2}{3}$ horse power during that hour.

To keep a steam engine of N horse powers in full activity during one hour, ought, therefore, to require a consumption of about $0.08 N$ kilograms of good coal.

But if really good steam engines, such as used in actual practice, are carefully tested, it is found (by H i r n) that they use about 8 times as much of coal, or about $0.64 N$ for N horse powers. At times the consumption of coal rises to 10 times the above theoretical amount ; in machines kept exceedingly well, and being well constructed, the amount has been found as low as 6 times the theoretical amount, or only about $\frac{1}{2} N$. kilograms.

Accordingly there is still much room for the improvement of the steam engine. For an engine using 6 times as much as is theoretically sufficient, returns only one-sixth or $16\frac{2}{3}$ per centum, wasting $83\frac{1}{3}$ per cent ; and this is the waste of the best steam engines ; while a machine using 10 times the necessary amount of fuel, renders only one-tenth the full amount of duty—that is, it gives 10 per centum of useful effect against 90 per centum of waste, *El. Phys.*, 88.

In fact, a machine which consumes one kilogram of good coal per horsepower per hour is really a very good machine, as now made. But 1.00 kgr. is more than 12 times the theoretical 0.08 sufficient to produce this power!

Such a good machine hardly yields 8 per cent, wasting fully 92 per cent of the fuel burnt !

84. In view of these strange facts it may well be asked, why are steam engines used if they are so wasteful ?

The reply is : the low price of coal. Even at such enormous wastes, the power obtained by burning coal under the steam boiler is exceedingly cheap when compared to the cost of an equal power produced by muscular effort of beasts—and still more cheap if compared to the price of human muscular effort.

Nevertheless, the above results of the scientific test of the steam engine are of the utmost importance, because they open to the scientific inventor a great field of useful labor.

The construction of the muscular frame as a machine, is certainly not better than that of the steam engine for work. As to actual cost, there is, as already stated, no comparison. The following may show this fact in detail :

The mechanical work (external) of one man per day is about 100,000 kilogram-meters. But one kilogram good coal burnt, yields, theoretically, 3,400,000 kilogram-meters ; that is, one kilogram of coal is, theoretically, equivalent to one day's work of 34 men. In average steam engines 12 times the theoretical amount of coal is consumed ; hence, the combustion of one kilogram of good coal under the boiler of a steam engine of average quality is equivalent to the mechanical labor of 3 men during one day. Accordingly, so long as the day's wages of one man exceed the price of $\frac{1}{3}$ of a kilogram of good coal, so long will the steam power of average machines be cheaper than the mechanical power of the muscles of man. But, to obtain even this result, the three men consume more than three kilograms of food !

Besides, the steam engine is infinitely more compact

than any other: in a comparatively small space it performs an immense amount of work. Even if men or beasts could work with the speed of the locomotive of 200 horse power, the system of platform wagons holding the necessary number of men or beasts would introduce friction enough to leave but little for actual pull on a train. How many men's service, at 100,000 kilogram-meters per day's work, would be required to substitute the day's work of a locomotive of 200 horse power? By answering this question the compactness of the steam engine will need no further demonstration, see 78 and *El. Phys.*, 86.

85. By the formula, A, in 82, we can readily calculate the amount of work, in gram-meters which the combustion of one gram of the substances enumerated in 47 can perform, if the heat were completely utilized.

Of course, the combustion of one kilogram produces the same number of kilogram-meters here given:

GASES AND LIQUIDS.		SOLIDS.	
Hydrogen.....	14,645,500	Anthracite.....	3,807,000
Olefiant gas	5,877,000	Charcoal	3,636,000
Olive oil.....	4,437,005	Coal, good.....	3,600,000
Ether.....	4,063,000	Coke	3,600,000
Alcohol.....	4,032,000	Wood, dry	1,801,000
Wood spirits....	2,385,000	“ moist....	1,395,000

The amount of mechanical work which can be performed by the process of combustion is therefore really immense. The combustion of one kilogram of hydrogen would lift a million kilograms 14.6 meters high! The combustion of one kilogram of coal would lift one hundred tons of coal 36 meters high!

86. In the same manner we may consider the different states of aggregation of the same substance as differing in a certain, fixed amount of mechanical work. For example, the states of water, the thermal differences of which are given in 69, become by the mechanical equivalent of heat:

1 gr. ice of $0^{\circ} + 35,665$ dyn. = 1 gr. water of 0° .
 1 gr. water of $0^{\circ} + 42,500$ dyn. = 1 gr. water of 100° .
 1 gr. water of $100^{\circ} + 229,225$ dyn. = 1 gr. steam of 100° .
 and therefore also
 1 gr. ice of $0^{\circ} + 307,390$ dyn. = 1 gr. steam of 100° .
 and also,
 1 gr. steam of $100^{\circ} - 307,390$ dyn. = 1 gr. ice of 0° .

The dynamo (El. Phys. 84) here used is one gram lifted one meter, or the gram-meter, because the unit of weight here used is the gram. The same figures also give the commercial values, by inserting kilogram instead of gram, when the dynamo also will be the kilogram-meter and the calories become kilo-calories.

87. Water lifted up to a height is still water, but by sinking it will again expend the work done in lifting it up. (Compare El. Phys., 98, 99, 100.) Thus we have also:

1 gr. water at the level of the sea + 100 dyn. = 1 gr. water at the level 100 meters.

Inversely,

1 gr. water at 100 meters above the surface of the earth—100 dyn. = 1 gr. water at the surface of the earth.

These relations are apparently similar to those in 86. We may therefore properly speak of the different states of aggregation as occupying different mechanical levels. The solid state is the lowest, the liquid intermediate, the gaseous highest.

88. In each state of the substance the mechanical level may be gradually changed by slowly raising its temperature; suddenly, however, when its state of aggregation is raised. Hence the numerical values in 86 are represented graphically by figure 12, drawn to the scale of 10,000 gram-meters to one millimeter. The drawing represents a terrace, the steep, precipitous banks corresponding to sudden changes in the state of aggregation, while the gentle slopes represent the substance in the different states.

Just as the water flowing down a hill or a precipice, sets free an amount of mechanical work proportional to the descent, so all materials in cooling may be made to perform mechanical work in amount proportional to this cooling; but at certain temperatures, a further cooling is accompanied with a change in state of aggregation exactly corresponding in mechanical work to a precipice in the flow of water.

89. Inversely, by using formula B, of 82, we can calculate the amount of heat equivalent to any given amount of work.

Thus, the external work of one man is (El. Phys., 86) about 100,000 kilogram-meters per day. But this is equivalent to 2,400 kilogram-degrees, which result from the combustion of 0.267 kilograms of alcohol, or from the combustion of 0.069 kilograms of hydrogen. (See 47.)

So also, if a cataract carries 100 litres of water per second down a precipice of 100 meters, the 10,000 kilogram-meters produced are equivalent to 240 kilogram-degree, and will raise the temperature of the water 2.4 degrees. provided there be no motion in the water below the fall. The presence of the surf, and especially of spray, will diminish this rise in temperature.*

90. By reference to the concluding articles of the Elements of Physics we now see, how heat takes its place in the complete circuit of physical agencies which are produced one by the other in the most different manner, but always in equivalent amounts. Just as impossible as it is to produce a particle of matter, except by an equivalent portion of already existing matter, so impossible it is to produce any of the physical agencies—light, heat (including combustion), electricity, magnetism, mechanical translocation (work), except by an interchange in equivalent proportion.

*The water of the Niagara is colder below than above the falls, on account of spray, surf, and evaporation.

Accordingly, physical science considers all these agencies as the same in kind, which we call displacement, locomotion. The apparently more subtle agencies are various states of motion and displacement of the particles of matter—motions discerned by reason's eye, armed by modern science; in the coarser agencies of running water or sinking weights, we have the joint motion of all particles as one, visible to the bodily eye and familiar to us from our earliest childhood.

CHAPTER III.

DISSOCIATION AND ELECTROLYSIS.

91. When a few small crystals of blue vitriol are gently heated in a dry, narrow glass tube (or in a watch glass, heated on a sand bath) they turn into a white powder, while the colder parts of the tube are coated with drops of water. Blue vitriol, by heat, thus is broken up into water and a white substance. If to this latter (after it is cooled) a few drops of water are added, the white color is again changed to the original blue, and much heat is involved during this change.

92. This action of heat is different from both fusion and volatilization; it is termed dissociation, because the one given substance (blue vitriol) was separated, decomposed into water and the white powder.

The white powder which remains is termed copper sulphate.* Hence blue vitriol consists of copper sulphate and water. Substances which contain water are termed hydrated. Therefore, blue vitriol is also called hydrated copper sulphate. The water in the blue vitriol is essential to the crystal form of the latter; for the expulsion of the water also destroyed the crystal form. Such water is often termed water of crystallization, and it can always be expelled by proper heating.

93. All crystallized substances which contain water of crystallization, may therefore be dissociated; that is,

*For it can be obtained from copper and sulphuric acid, as shown in a subsequent chapter.

they can be decomposed by heat alone. The water of crystallization will be expelled, and a residue free from water (*i. e.*, anhydrous) will remain.

The amount, w , of the water of crystallization in one gram of crystals, is determined by carefully heating from $\frac{1}{2}$ to 1 gram of rather small crystals in a watch glass on a sand bath until it ceases to loose in weight. You weigh the watch glass alone ($=a$), with the crystals on ($=b$), and with the residue* ($=c$); then $w = \frac{b-c}{b-a}$ grams.

Blue vitriol is by far the best example for practice. Green vitriol, white vitriol, alum, and any of the Haueroids (*El. Phys.*, 194 and 195) may also be used, and the amount, w , of water of crystallization determined as above. Among the minerals, gypsum, is the most proper example.

Some of the above crystals—especially alum†—first apparently fuse when heated, but only while yielding water; when all the water has been expelled, the white residue remains solid and is infusible. The fusion in the water of crystallization is termed aqueous fusion. The true fusion is distinguished as igneous fusion.

94. At a moderate heat on the sand bath blue vitriol dissociates into white copper sulphate and water (91 to 93). But if pulverized blue vitriol is heated on a small platinum dish or porcelain capsule, directly* over the flame, so as

*Do not weigh until cold. When *white*, you stop heating.

†Borax also contains much water of crystallization, which is expelled in making a borax bead. (See 27). If you weigh the platinum wire $=w$, also weigh off about one decigram of borax, $=b$, on a small piece of paper, and carefully make the bead

without losing borax, you will find the bead on the wire to weigh about w plus $\frac{b}{2}$, so

that about one-half of the borax is water of crystallization. Careful experiments give 47 per cent. of water and 53 per cent. of anhydrous matter.

*Supported on a platinum triangle, or iron-wire triangle whereof the wires are partly covered by pipe stems.

to be exposed to a red heat, it will rapidly turn white (by the above dissociation) and continue to change in color through brown to black. The black substance remaining is called black copper oxide, for reasons which will be given in a subsequent chapter (IV.); here it may suffice to state, that the same black substance is obtained by heating copper in a flame. The amount of copper oxide in blue vitriol may be determined by weighing the dish (= a), the same with blue vitriol (= b), and with the black oxide (= c); it will then be $\frac{c-a}{b-a}$ grams in one gram

95. By merely heating the black copper oxide it has not yet been further dissociated. However, it is not doubted that exposure to a sufficiently high temperature will dissociate it again, leaving metallic copper; but, as stated, this dissociation has, so far, never been accomplished.

If we assist the dissociating action of heat by the reducing flame of the blow-pipe while the oxide is supported on the charcoal, (see 25), we can readily decompose the oxide, which thus yields metallic copper.*

96. But neither by simple dissociation nor by any auxiliary to heat, has copper ever been dissociated or decomposed in any way. It is, therefore, so far as we are able at present to ascertain, a simple substance, or a chemical element.

The following is the most correct definition of this term:

*A still more simple reduction to the metallic state is the following;

A small fragment of silver nitrate—one centigram is quite sufficient—is placed upon charcoal and the blow-pipe flame directed to a spot near the nitrate. When this spot of coal begins to glow, the nitrate suddenly spreads over the red hot charcoal, burning the latter violently [deflagration], and leaving a white residue of silver, which exhibits most beautifully the fibrous structure of the wood of which the charcoal was made. By removing the silver spot with the penknife a very fine object for the microscope will be secured.

By pressing the silver with the knife, it is burnished. It may also be fused to a globule on charcoal.

A chemical ELEMENT is a substance which has not yet been decomposed; neither by heat alone (dissociation) nor by heat aided in any manner whatever.

A chemical COMPOUND is a homogeneous substance which can be dissociated or decomposed.

A MIXTURE is a substance which is not homogeneous; it can usually be separated by mechanical means into several elements or chemical compounds.

It is not necessary to give additional examples here, because these terms will gradually become more thoroughly understood by the frequent examples in the following.

97. The principal difference between compound and mixture may be expressed in the following two statements :

1. Chemical compounds contain their constituent components in fixed proportions; mixtures may be made in any proportion.

2. A chemical compound differs from the sum of its constituent components by a certain amount of heat or mechanical work; a mixture does not differ in this manner.

Thus, in the above example of blue vitriol, we shall find a fixed amount of white copper sulphate, and a fixed amount of copper oxide by dissociation. One gram of blue vitriol leaves always 0.64 grams of copper sulphate and finally 0.32 grams of black copper oxide; which latter before the blow-pipe (95) always yields 0.25 grams of metallic copper.*

So, also, blue vitriol is not simply the sum of copper sulphate and water, but less than this sum by a con-

*The blue vitriol should be mixed with about twice its weight of sodium carbonate if the experimenter is to succeed; it is rather too difficult for the beginner.

siderable amount of heat (or of mechanical work, see 82). That is:

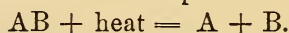
Copper sulphate + water = blue vitriol + heat.

The amount of this heat may be determined by the calorimeter (44). We shall soon see that combustion is the combination of the combustible with oxygen; hence all the examples given in 47 and in 85 may now be referred to as demonstrations of the second of the above statements.

98. As a rule, direct combination yields heat, and direct decomposition requires heat. That is, if A and B are substances, then if they can be combined directly to the compound A B, without any intermediate agency, we shall have in synthesis or direct combination:



and in analysis or decomposition:



Thus the fuel = A, combining directly with the oxygen (of the air) = B, gives the product of combustion AB and heat; to reproduce the fuel, A, and the oxygen, B, from this product of combustion, AB, would require the expenditure of an amount of heat equal to that produced in the combustion. Compare 85 and 47.

These general results will be further utilized when we shall have become familiar with a sufficient number of additional facts.

99. Mercuric oxide* is also readily dissociated by gently heating about half a decigram thereof in a small dry, test tube. The latter should be held obliquely so that the flame plays on the spot where the oxide lies. The oxide quickly turns deep brownish red, and soon has entirely disappeared. But it has not volatilized (see 54): it has dissociated into metallic mercury and gaseous oxygen!

*Commonly called red oxide of mercury.

The metallic mercury will be seen forming a beautiful mirror around the colder parts of the tube, the mirror being composed of minute globules of metallic mercury.

That a peculiar gas has been given off at the same time, will be recognized by bringing the glowing point of a small splinter of dry pine wood down into the tube;* the splinter will begin to burn with great vivacity.

The gas thus formed and characterized by its energetically supporting combustion is called oxygen. It has, so far, proved to be an element. See 96.

100. The teacher may collect a greater quantity of oxygen over water (see *El. Phys.*, 127) by heating a larger amount of mercuric oxide† in a glass flask connected with the gas receiver by means of a rubber tube. He may then also exhibit the fact that oxygen most energetically supports combustion by some of the most beautiful chemical experiments, such as the combustion of the stearine of a downward turned lighted candle—the combustion of sulphur, carbon, and steel in oxygen. Hence: combustion is the combination with oxygen.

At the same time the student will notice that oxygen is a colorless gas, destitute of odor. It is a little heavier than atmospheric air, one cubic centimeter weighing 1.430 milligrams. (Compare *El. Phys.*, 33). The presence of oxygen is always proved by the glowing shaving or splinter as above described (test for oxygen.)

Larger quantities of oxygen are obtained by the dissociation of potassium chlorate. (Description of its crystals, *El. Phys.*, 179.) It leaves potassium chloride, which is

*In order that the experiment may succeed, the tube must not be moved, otherwise the gas mixes with the air around the tube.

†One gram of mercuric oxide yields about 55 cc. of oxygen.

isomorphous with sodium chloride (El. Phys., 188). One gram of the potassium chlorate yields 280 cubic centimeters of oxygen gas. To avoid the almost explosive rapidity of the evolution of the gas from this chlorate, the latter is mixed with manganese dioxide* (black oxide of manganese). Other methods of preparing oxygen have only importance to the teacher.

101. The following experiment most beautifully demonstrates both analysis (by dissociation) and synthesis (uniting together). The student should follow the directions to the letter.

A minute quantity (1 cgr.) of mercuric oxide is heated in the closed end of a small blow-pipe glass tube (28), the closed end being heated in a small flame. The chemical process taking place is, as explained above, 98.

Mercuric oxide + heat = Mercury + Oxygen.

If now a few minute crystals of iodine ($\frac{1}{2}$ cgr.) are dropped into the tube, they will volatilize if the bottom of the tube is still hot—otherwise, heat gently. As the purple vapors reach the mercury globules, the latter will disappear, and be replaced by a yellow (or red) ring. By gently heating the tube from the bottom till a little above the mercury mirror, and then permitting the whole to cool, beautiful microscopic crystals of yellow or bright red mercuric iodide will be seen in the tube under the magnifier or by the microscope. If yellow crystals remain, they will slowly change to red; by rubbing them with a hard body (such as a glass rod or an iron wire) they will change quickly in color. If there was more of iodine than the mercury can combine with, a black ring of (partially crystallized) iodine will be seen above the red iodine; if not enough iodine had been taken, some metallic mercury will remain in the tube.

*This should itself be tested by heating a small portion of it with chlorate in an open cup; if organic matter be present, a slight explosion will take place and the oxide cannot be used for the preparation of oxygen.

Iodine has so far proved to be an element; so has mercury. Hence we have in the above experiment the direct synthesis of two elements, iodine and mercury. The compound resulting is called mercuric iodide, as already stated.

102. At a very high temperature water has been dissociated into two gases, namely: oxygen and hydrogen.

By means of the galvanic current, water is much more easily decomposed than by means of heat. Compare *El. Phys.* 388, 390. The electrolysis of water may be exhibited to the class by Hofman's apparatus, figure 13. The two branches, A B, are about 30 cm. long; they are completely filled with water, acidified with sulphuric acid, from the reservoir, C, by opening the stop cocks in A and B. Near the lower end of A and B platinum wires with foil have been fused through the glass, and serve as electrodes.

When the poles of a battery of two or more Bunsen cups are connected with the platinum wires of A and B, a multitude of gas bubbles arise, and collect at the top of these tubes as shown in the figure. The gas in the tube which is connected with the positive pole of the battery is found to be oxygen; for the glowing shaving, held in the current of the gas produced by opening the corresponding stop-cock, bursts into flame. The gas in the other tube, connected with the negative pole of the battery, is called hydrogen; by opening the corresponding tube and bringing a flame near the gas current, the latter will be kindled, burning with a pale bluish flame. A dry glass vessel inverted over this hydrogen flame will become dim from the deposition of dew, indicating that the product of combustion of hydrogen is water.*

*In order that this experiment may be quite demonstrative, the hydrogen gas should be carefully dried (157); but for common lecture purposes it may suffice to state, that the carefully dried hydrogen gives the same result as above.

It will also be seen that the volume of hydrogen gas is always exactly double that of oxygen. Hence,

Water + galv. Electricity gives 1 vol. Oxygen + 2 vols. Hydrogen.

By careful experiments it has also been proved that a mixture of any volume of oxygen with twice as great a volume of hydrogen explodes by an electric spark or by a flame, and yields no matter but water* — while producing at the same time much heat. (Compare 47.) Hence,

1 vol. Oxygen + 2 vols. Hydrogen = Water + Heat.

For the student's experiments on the gases produced by the electrolysis of water, the apparatus, figure 13, is most convenient. It consists of a bent glass tube, A B C, 1 cm. wide and each branch about 20 cm. long. One end, C, is closed by means of a cork and sealing wax; a platinum wire, to which a piece of platinum foil is attached, passes through the cork. In the open branch a like wire with foil is inserted. The tube is filled with acidified water from C to a little above the foil in A; this is readily done by holding the tube with C downwards. The galvanic current is now passed through the water by touching the platinum wires with the connecting wires of the battery; always touch the wire in C with that pole which gives the gas you wish to examine. If you therefore wish to examine hydrogen, touch C with the negative pole; if you want to experiment with oxygen, touch C with the positive pole wire.

When, by the collection of gas in C, the level in A B has been pushed quite up to the end, A, of the tube, disconnect the battery, take out the wire from A B, close A with the thumb, invert the tube so that the gas is transferred from B C to B A; upon now removing the thumb the gas may be tested at pleasure.

*A dry glass held inverted over any flame of common combustibles (wood, stearine, kerosene, gas, etc.,) will be coated with dew or water. Hence these combustibles do contain hydrogen.

If your battery is not strong enough to fill the tube as stated, you may fill up A B by water, and proceed as above.

103. If a considerable volume of hydrogen is collected the following properties of hydrogen may be recognized :

Hydrogen is a colorless gas, without odor, and lighter than any other body, one cubic centimeter weighing only 0.0896 milligrams, (El. Phys., 32). It has never yet been liquefied; nor has it in any way been decomposed, so that it is considered a chemical element (see 96). It is easiest recognized by its combustibility.

The latter fact requires great care in the experimentation with hydrogen; for if mixed with oxygen or common air, it will explode when the flame is brought in contact with the mixture. Hence the vessels wherein hydrogen is produced, should always be freed from air; this is easiest done by continuing the evolution of hydrogen long enough.*

104. If a considerable quantity of hydrogen is required it is usually obtained by the action of dilute sulphuric acid on zinc (172). One gram of zinc requires $1\frac{1}{2}$ gr. of sulphuric acid, and yields about 3 centigrams of hydrogen, which occupy a volume of about 330 cubic centimeters.

By means of the hydrogen thus produced various experiments may be exhibited by the teacher, especially the combustion of hydrogen and oxygen in the *Oxyhydrogen blow-pipe*. The flame of this blowpipe is exceedingly hot, but not luminous; iron, and especially steel, burn in it with intense scintillations, and platinum fuses readily in the same.

105. In electrolysis hydrogen passes to the negative pole; hence hydrogen is considered the *electro-positive*

*From time to time collect a test tube full of the gas, and carefully light it. If it burns without an explosion, the gas is pure, and free from air.

tive component of water. For the same reason oxygen is considered the electro-negative component of water.*

In blue vitriol the metal copper is accordingly the electro-positive component.

By passing the galvanic current through all sorts of substances, the metallic component invariably appears at the negative pole, either pure (as in the case of copper, silver, mercury and other metals) or combined (as in the case of the more combustible metals, magnesium, etc). Hence, in general, the metals are the electro-positive constituents of compounds.

Those elements or compounds which in electrolysis appear at the positive pole, are termed electro-negative elements, or compounds.

*For like electricities repel; unlike attract each other. See El. Phys., 352.

CHAPTER IV.

ELEMENTS AND COMPOUNDS.

106. More than sixty substances have, so far, never been decomposed, either by heat (dissociated) or by the galvanic current (electrolysis) or in any other manner. These substances are therefore considered as chemical elements.

All other substances are either compounds or mixtures. (See 96 and 97.)

107. The greater number of the chemical elements are metals, that is, bodies endowed with metallic lustre, and malleability. (El. Phys., 147, 208,.) The properties of opacity and tenacity are, in different degrees, associated with the above, as well as the conductivity for electricity (El. Phys., 366) and heat (34).

The elements not endowed with these properties are termed metalloids.

The ancients knew only 9 of the substances now recognized as elements; namely the metals: gold, silver, mercury, copper, iron, tin, lead and the two metalloids: sulphur and carbon.

108. Since so many elements now are known, it is important to classify them carefully into groups of elements closely resembling each other. A group of similar elements is called genus of elements. The individual elements in each genus are termed the species of elements.

In this volume we consider only full genera, together with two genera each represented by only one species.

We shall name these genera by attaching the suffix -oids to the characteristic part of the name of the most prominent element of the genus.*

The following is a list of the genera of elements in the proper order :

GENUS.	SPECIES.	LATIN NAME.
1. Kaloids, resembling	Potassium	(Kalium).
2. Calcoids	Calcium.	
3. Cadmoids,	Cadmium.	
4. Cuproids,	Copper.	(Cuprum.)
5. Ferroids,	Iron	(Ferrum)
6. Titanoids,	Titanium.	
7. Phosphoids,	Phosphorus.	
8. Sulphoids,	Sulphur.	
9. Chloroids,	Chlorine.	

Between 3 and 4 stands mercury (Hydrargyrum), the only representative of the Hydrargoids. The element hydrogen may be placed both at the top and at the bottom of this list; in the first place if it is metallic in its relations, (and may be called hydrogenium), while in the latter case it acts like a metalloid. Also Boron and Tin are here given as single elements—representatives of genera not here described.

109. The order of the genera above given is determined by the deportment of the elements in high temperatures. The least fusible and volatile is placed in the middle. The most fusible and volatile are at the top (genus 1) and at the bottom (genus 9); the metals standing above, the metalloids below. The upper elements in this table are decidedly electropositive;† the lower equally

*Only if that element has a name unfit to take the suffix shall we name the genus after one of its less important members; as in case of genus 3 and 6.

†Determined especially by the deportment of compounds in electrolysis. The element passing to the negative pole is electro-positive, see 105.

electro-negative; the middle are positive in reference to the lower, and negative in reference to the upper. The different species in each genus are arranged from left to right in the order of their specific gravity. Thus the cuproids are copper, silver and gold; they are given in this order, because copper has the lowest, gold the highest, specific gravity of the three.

110. But the tabular view of the elements cannot readily be represented if the full name of the element is to be entered in the same. Besides, it is of very great practical importance to adopt some abbreviations or symbols for the elements in order to make all references to them as simple as possible.

The symbols of the elements were devised by Berzelius, and consist in the characteristic letters of the Latinized name of the elements. Thus potassium has the symbol *K a*, the characteristic letters of the Latinized (Arabic) name *Kalium*. Zinc has the symbol *Z n* (Latinized, *zincum*), lead *P b* (*plumbum*, Latin), iron *F e* (*ferrum*), gold *A u* (*aurum*).

In the same manner we use as symbol of the genus the characteristic Greek letters of the name of genus.

112. In this way results the following natural CLASSIFICATION OF THE ELEMENTS, first published by the author in 1867:

GENERA.		SPECIES.				
	I'	H.....electro positive.				
1	$K\alpha$	Li	Na	Ka	..	..
2	$X\alpha$	..	..	Ca	Sr	Ba
3	$K\delta$	..	Mg	Zn	Cd	Pb
	$I\gamma$	..	..	..	..	Hg
4	$K\upsilon$	..	..	Cu	Ag	Au
5	$\Sigma\epsilon$	..	Al	$\Sigma\delta$	Rh	Ir
6	$T\tau$	C	Si	Ti	Pd	Pt
	..	Bo	..	..	Sn	..
7	ϕ	N	P	As	Sb	B
8	θ	O	S	Se	Te	..
9	X	Fl	Cl	Br	Io	..
	I'	H.....electro-negative.				

The symbol $\Sigma\delta$ stand for the following varieties of elements :

$\Sigma\delta$ Cr Mn Fe Ni Co Ur

112. In order to learn the signification of these symbols, we give an alphabetical list of the same, together with the common name represented by the symbol. The Latin name has been added in all cases where the derivation required it.

SYMBOL.	NAME, COMMON.	LATIN.
Ag.....	Silver.....	Argentum.
Al.....	Aluminium.	
As.....	Arsenic.	
Au.....	Gold.....	Aurum.
Ba.....	Barium	
Bi.....	Bismuth	
Bo.....	Boron	
Br.....	Bromium	
C.....	Carbon	
Ca.....	Calcium	
Cd.....	Cadmium	
Cl.....	Chlorine	
Co.....	Cobalt	
Cr.....	Chromium	
Cu.....	Copper.....	Cuprum.
Fe.....	Iron.....	Ferrum.
Fl.....	Fluorine.	
H.....	Hydrogen.	
Hg.....	Mercury.....	Hydrargyrum.
Io.....	Iodine.	
Ir.....	Iridium.	
Ka.....	Potassium.....	Kalium.
Li.....	Lithium.	
Mg.....	Magnesium.	
Mn.....	Manganese.	
N.....	Nitrogen.	
Na.....	Sodium.....	Natrium.
Ni.....	Nickel.	
O.....	Oxygen.	
P.....	Phosphorus.	
Pb.....	Lead.....	Plumbum.
Pd.....	Palladium.	
Pt.....	Platinum.	
Rh.....	Rhodium.	
S.....	Sulphur.	

SYMBOL.	NAME, COMMON.	LATIN.
Sb	Antimony.....	Stibium.
Se.....	Selenium.	
Si	Silicon,	
Sn.....	Tin.....	Stannum.
Sr	Strontium.	
Te.....	Tellurium.	
Ti	Titanium.	
Ur.....	Uranium.	
Zn.....	Zinc.	

113. The symbols of the genera, also in alphabetic order, are:

SYMBOL.	NAME.	PRONUNCIATION OF SYMBOL.
θ	Sulphoids.....	Theta.
Ka	Kaloids.....	Kappa-alpha.
$K\delta$	Cadmoids.....	Kappa-delta.
Kv	Cuproids	Kappa-epsilon.
Σi	Ferroids.....	Sigma-iota.
$\Sigma\delta$	Sideroids*.....	Sigma-delta.
$T\tau$	Titanoids.....	Tau-tau.
Υ	Pantoids.....	Upsilon.
$\Upsilon\gamma$	Hydrargoids	Upsilon-gamma
Φ	Phosphoids	Phi.
X	Chloroids	Chi.
Xa	Calcoids	Chi-alpha.

114. The student† should make himself quite familiar with the following simple characteristic of the system of the elements:

*The group Cr., Mn., Fe., Ni., Co., all very nearly alike, as if they were varieties of the species Fe. The element Ur., also is allied to this group.

†The teacher should exhibit as many of the elements as possible, in small specimen tubes. Also some of the phenomena—as combustion of Ka . on water—should be shown to the class. On a wooden tablet, one meter square, the systematic classification, 112, should have been painted, so that the teacher with chalk can write boundary lines, etc. The student should enter these lines on the blanks of 112, printed in the Journal. See fig. 15.

I. The elements above the full drawn boundary line, (figure 15) have metallic luster; the elements below the line have no metallic luster. The former are usually called metals, the latter metalloids.

II. The metals below and to the right of the dotted line are called heavy metals, because their specific gravity is above 5; the other metals are called light metals.

III. The kaloids are most strongly electro-positive; the chloroids are most strongly electro-negative. The other genera have been arranged according to their electric property; each genus being positive in reference to the genera below, and negative to the genera above.* Accordingly Aluminium and all of the heavy metals are found both as electro-positive (towards the metalloids) and as electro-negative (towards the kaloids and calcoids) in combinations. Compare 109.

IV. The elements below the fine drawn line (figure 15) are gaseous; all the other elements are solids, except Bromine and Mercury, which solidify respectively at -7° and -40° . Of the gases, chlorine has been liquefied; but hydrogen, oxygen, and nitrogen have not yet been liquefied, and are therefore called permanent gases. Fluorine is but very little known.

115. The following simple characteristic of the genera should be studied in the same manner as in 114:

1. Kaloids, *Ka*. Very soft, lighter than water, very fusible, exceedingly volatile and combustible, white metals, coloring the flame; cannot be reduced

*Hydrogen at the top is the metallic hydrogenium of Graham; it is electro-positive, but as yet only known alloyed with Palladium.

Hydrogen at the bottom is electro-negative, occurring in Hydrates. See further on.

by the blow-pipe. (See 25 and 95.) Do not impart color to their compounds.*

2. *Calcoïds*, $\Lambda\alpha$. Rather hard; heavier than water; fusible, not volatile; highly combustible; whitish (yellow) metals, coloring the flame. In regard to compounds and reduction as 1.

3. *Cadmoids*, $K\delta$. Rather soft; moderately heavy; very fusible and volatile; bluish white metals; combustible, coloring the flame but faintly. Impart no color to their compounds. All reducible by blow-pipe except the most combustible, Mg .†

Mercury, Hg . Liquid; very heavy; very volatile; not readily combustible; grayish white metal. Rather intermediate in its properties between Ag and Pb .

4. *Cuproids*, Kv . Moderately hard, heavy, fusible; faintly volatile metals, possessing metallic luster and malleability in the highest degree. Not combustible except Cu , which colors the flame green. Very easily reducible by blow-pipe; all compounds of Ag and An dissociated by heat. Compounds of copper usually colored (commonly green and blue).

5. *Ferroids*, $\Sigma\alpha$. Hard, heavy, difficultly fusible, non-volatile, grayish white metals, some of which have highest degree of tenacity (Fe). The lighter ones combustible; all but the light metal, Al , reducible before the blow-pipe.

The *sideroids*, $\Sigma\delta$, embrace five metals most closely allied to iron; they occur usually together, and strongly color their compounds. They are magnetic, especially Fe , Ni , Co . The element Ur is related in the sideroids.

*Teacher: burn $K\alpha$ on water; obs. flame. Show metal properly incased between two test tubes (sliding into one another) and bees' wax. Na is now manufactured in large quantities.

†Burning Mg . wire before class. Student practice on minute portions of Mg ., Zn . and Pb . [1 cgr. each] in o-fl of blow-pipe. Note color and size of incrustation. Compare —.

6. **Titanoids, $T\tau$.** Mostly heavy, all infusible, non-volatile elements; the lighter ones* combustible and non-reducible; the heaviest non-combustible and easily reducible.

7, 8, 9. The elements of these genera resemble the type-element (P, S, Cl); otherwise the properties gradually increase towards the metallic with the increase in specific gravity, that is, towards the right in each genus. Thus Bi has high metallic luster, is usually called a metal, but it is brittle.

In regard to combustibility and reductibility, we must refer to the subsequent parts of these elements.

116. The student may now ascertain the **pyrognostic properties** of the principal elements, that is, the deportment of the element in high temperature. Thereby the above characteristic, 115, will become more firmly grounded in his mind.

The teacher should give the student a few minute fragments (each about one centigram) of the element; also blow-pipe and charcoal, see 25.) The student carefully notices the physical properties (see *El. Phys.*, 216) especially the four optical and the molar properties; then heats one of the fragments steadily in the fusing point of the blow-pipe flame, and carefully observes: fusing, volatilization, combustion (flame coloration), and incrustation, as to color and size, both hot and cold. Also notices odor and fumes, if any. Finally compares results to the general characteristic in 115.

If an additional larger piece is given, the student may also determine hardness, H, and specific gravity, G; otherwise, the teacher better state these two properties on the label, for the student to enter in his description in parenthesis.

*The common varieties of coal are impure carbon.

The properties should be recorded in the following order:

No. DESCRIPTION OF.

Optical: Opacity—Luster—Color—Streak.

Molar: H. G. Cleavage: malleable ? brittle ?

Pyrognostic: Fus.—vol.—combust ? incrust., etc., etc
Odor ? Fumes ? Magnetic ?

117. After the student has thus become personally acquainted with pyrognostic properties of some of the most common elements, he may examine some of the compounds of the elements in the reducing flame. First, the substance alone; next, the substance mixed* with about twice its amount of sodium carbonate. He may then often be able to determine the metal in the compound.

Results should be recorded in the Journal precisely as in 116.

It is absolutely essential that the student should take no larger quantity than directed — of elements never more than about a centigram, and of compound rather less yet. The blow-pipe flame should be steady, and well defined; compare 23.

II. CHEMICAL NOMENCLATURE.

118. All matter being composed of the comparatively small number of chemical elements, it follows that the number of chemical compounds is practically infinite. On this account it is highly important that these compounds should be classified and named according to some simple and rational method. The following classification and nomenclature is quite generally used; for the sake of further simplification we have added a concise notation.

119. Substances are first classified into *Monaries*, *Binaries*, *Ternaries* and *Serials*.

*On a piece of paper, by blade of penknife.

Monaries are the chemical elements themselves. Binaries are compounds of any two elements. Ternaries are combinations of any three elements. The serials are peculiar compounds of carbon, with one or more of the following elements: hydrogen, oxygen, and nitrogen. They occur quite abundant in animals and plants, and therefore are often termed organic compounds. But many of these serials have been prepared from their elements in the laboratory, mostly by successive condensations or additions, so that their particles appear to form strings or series of particles of the constituent elements. Hence the name whereby these compounds here are designated.*

Compounds containing water in addition are commonly classified as hydrated in connection with the compound resulting by the removal of the water. Thus blue vitriol is classified with the sulphates. (See 92.)

120. The elements are named as explained above. Any element is often symbolized by the letter R (abbrev. of radical). Any electro-positive element will be designated by the Greek letter π ; any electro-negative element by the Greek letter ν . Any element interme-

*The following may serve to give a more distinct idea of what is meant by serial compounds:

When petroleum is subjected to careful fractional distillation, a number of volatile liquids are obtained differing from one another by about the same number of degrees in boiling point; the specific gravity of these liquids increases quite regularly with the boiling point, and the specific gravity of the vapors increases from one to the next by exactly seven times the amount of the specific gravity of hydrogen, that is by 0.627 mgr. for the cubic centimeter. These substances furthermore all consist of carbon and hydrogen in very nearly the same proportion. These are called Paraffins, and distinguished as the I., II., etc., in the series of Paraffins.

The n th member in this series contains 1 plus $\frac{1}{n}$ part of hydrogen for each 1 of carbon; the specific gravity of its vapor is exactly 1 plus 7. n times the specific gravity of hydrogen; the specific gravity in the liquid form is about 0.08 plus 0.43. n . The members [$n = 1, 2, 3$ and 4] are gaseous at common temperatures, while the next following are liquids, and the highest members are solids.

Thus these compounds form a regular series in every respect; and it is in this sense that they may be called serial compounds. Of such series of compounds a great many are known, and the organic materials have all a composition of precisely this serial nature.

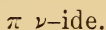
diate, combining with either of the above, may be designated by ϵ .

121. A Binary is a chemical combination of any two elements. Since now any element is either electro-positive or electro-negative in reference to any other, a binary must always consist of one element which is electro-positive in reference to the other. Hence any binary may be represented by



the electro-positive always being written first. Most commonly π is a metal and ν a metalloid. (Compare 114, also 101.)

The scientific name of such binary consists of two words, namely, the full name of the electro-positive element, π , followed by the essential portion of the name of the electro-negative element, ν , to which the suffix *ide* has been appended. Hence the name of any binary may be represented by



For example, the binary resulting from $\pi =$ Mercury and $\nu =$ iodine in 101, is called Mercury iodide. Oxygen combined with mercury gives Mercury oxide.

For the sake of brevity these names may also be written by using the symbols, thus: Hg Io-ide Hg O-ide.

122. However, at times the same two elements combine in more than one proportion. Thus mercury and iodine combine in two different proportions, namely, one gram of mercury with 1.27 gr. iodine in the above mentioned iodide (see 101), but also with half as much iodine (0.63 gr.) in a greenish iodide. These are distinguished by appending the suffix *-ic* or *-ous* to the characteristic part of the electro-positive.

The compound $\pi\text{-ic } \nu\text{-ide}$ contains more of the electro-negative, the compound $\pi\text{-ous } \nu\text{-ide}$ contains less of the electro-negative.

Accordingly the red iodide of mercury is called mercuric iodide, the green is called mercurous iodide. The mercuric oxide used in 99 and 101 is red; contains more of oxygen than the black oxide of mercury which is properly called mercurous oxide.

Abbreviated by the use of the symbols of the elements, these names will be Hg-ic Io-ide; Hg-ous Io-ide; Hg-ic O-ide, Hg-ous O-ide.

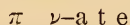
123. The proper classification of the binaries is by the negative element. Thus we describe not the various binaries containing the same π , but those containing the same ν in the same section. Hence we describe as separate classes of binaries the oxides ($\nu = \text{O}$), chlorides ($\nu = \text{Cl}$), iodides ($\nu = \text{Io}$), sulphides ($\nu = \text{S}$). In each of these the particular species is determined by the electro-positive π .

124. A ternary compound is a chemical combination of any three elements. The most electro-positive of these will be denoted by π , the most electro-negative by ν , the intermediate by ϵ . Hence

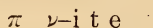


represents any ternary.

125. By far the most common case is $\epsilon = \text{O}$, that is, oxygen is the intermediate element in most ternaries. These oxygen ternaries are called



or



according as the amount of oxygen is greater or less. Thus copper sulphate and copper sulphite are both ternaries of copper, oxygen and sulphur; but the first contains more of oxygen than the latter—Abbreviated Cu S-ate and Cu S-ite.

Also here the suffixes -ic and -ous are appended to π as explained in 122. Cuprous sulphate contains rela-

tively less of sulphur than cupric sulphate—Abbreviated Cu-ous S-ate and Cu-ic S-ate.*

126. If the intermediate element ϵ in the ternary is not oxygen, it is either sulphur, chlorine, bromine, iodine, fluorine or the so-called compound radical cyanogen. In these cases the characteristic portion of the name of the intermediate element ϵ is used as a prefix to the name ν . Hence the name of these ternaries has the general form

π ϵ - ν -ate

or

π ϵ - ν -ite

where again both π -i c and π -o u s are used.†

Thus potassium cyano ferrate is a ternary, composed of potassium as the most electro-positive, iron as the most electro-negative, and cyanogen as the intermediate element. What is potassium chloro-platinate? Sodium fluo-aluminate? These names may be written in the following abbreviations: Ka Cl-Pt-ate; Na Fl-Al-ate; Ka Cy-Fe-ate.

127. The nomenclature of the serials cannot here be treated of; it must suffice to mention a few of the most prominent classes of serials.

The Hydro-carbons are serial binaries of carbon and hydrogen. In Petroleum, our illuminating fluids, in illuminating gas, we have mixtures of these. Some vola-

*If there are still further proportions of oxygen, then the prefix per is added for more, and hypo- for less of oxygen.

From the least to the greatest amount of oxygen thus six different grades, namely: hypo-v-ite, v-ite, per-v-ite, hypo-v-ate, v-ate, per-v-ate.

This number is quite sufficient. For $\nu = \text{Cl, N, P}$, several of these names are required.

†Ternaries can frequently be prepared by direct synthesis of two binaries. The binaries π ϵ -ide and ν ϵ -ide, will, if united, give the binary π ϵ - ν -ate. Hence, many chemists call such ternaries double binaries. For example, potassium chloride and platinum chloride combine directly; they yield the ternary potassium chloroplatinate. Many chemists call this compound, however, a double chloride of potassium and platinum.

Although in Pt Cl-ide, the chlorine is the negative element, in Ka Cl-Pt-ate it is the intermediate, between the two metals, the electro-positive Ka and the electro-negative Pt.

tile oils also belong to this class. See note to 119.

The c a r b o - h y d r a t e s are serial ternaries of carbon, oxygen, and hydrogen, the latter two in the proportion in which they would form water. Sugar, gum, starch, woody fibre are such serials.

Hydro-carbons with a certain amount of oxygen are ethers; with more oxygen they form alcohols, with most oxygen acids result. Common ether, alcohol, and acetic acid form good examples.

Certain compounds of nitrogen with carbon, hydrogen, and oxygen are called alca l o i d s. Such are strychnine, morphine, quinine.

128. The preceding notions of chemical nomenclature will enable the student to tell the elements in a substance if the correct scientific name is given to him. Again, if by s y n t h e s i s compounds are built up, the student will be able to give the proper name to each.

We shall now proceed to the synthesis of the principal binaries and ternaries.

CHAPTER V.

ACIDS AND BASES.

129. Phosphorus is ignited at a low temperature* and burns with emission of a brilliant light, producing at the same time a white smoke. The white particles are therefore phosphoric oxide; if the supply of air is limited, phosphorous oxide results.

Both of these oxides are readily absorbed by water, which thereby assumes an acid taste and turns blue litmus paper† red. Hence the solution of these oxides in water are termed acids; respectively phosphoric acid and phosphorous acid.

For lecture purposes the teacher should burn about $\frac{1}{8}$ gram phosphorus, supported on an iron deflagrating spoon in a large, loosely closed, dry flask (figure 16); then add some water, which will dissolve the dense white fumes and yield a dilute solution of phosphoric acid. If this solution is evaporated, a syrupy liquid of concentrated phosphoric acid results, finally pure solid phosphoric

*Hence phosphorus is to be preserved under water, and handled with much care. Only a small piece is used at a time. If to be cut off, this is done under water. Before use for combustion phosphorus is carefully dried between blotting paper. The dried phosphorus only should be used for combustion; to light it, touch it with a heated wire.

†The so-called litmus is a vegetable blue coloring material. It dissolves partly in water. Fine printing paper soaked in such solution and dried constitutes the blue litmus paper. It is cut into small strips, about 2 mm. wide and 30 mm long, called blue test paper. These strips are preserved in the dark [closed boxes, etc.,] for by light they are soon bleached.

When the blue litmus solution is just reddened by the least possible amount of a dilute acid [sulphuric] and paper drawn through the reddened solution, we obtain the so-called red litmus paper, which is cut and preserved precisely as the blue paper. For its uses, see below.

acid will be obtained (the so-called glacial phosphoric acid). When a small portion of this acid is thrown into water, it dissolves, heating the water very much.

Since phosphorus in combustion necessarily (100) gives an oxide, and since water is also an oxide (hydrogen oxide, see 102), it follows that phosphoric acid is a ternary, composed of hydrogen, oxygen, and phosphorus. The latter is electro-negative in regard to the first. Oxygen is the intermediate element, so that the scientific name of this ternary is hydrogen phosphate. Abbreviated H P-ate. Compare 125.

If the tube (130) with both its branches is held nearly horizontal, the phosphorus cannot get as much oxygen, and phosphorous oxide will result. This will yield hydrogen phosphite when dissolved in water. Abbreviated H P-ite.

A still more imperfect combustion of phosphorus yields the so-called hypophosphorous oxide, which in water produces hydrogen hypophosphite.

All of these solutions are acid (*i. e.* redden blue test paper); hence they are often spoken of as the acids of phosphorus.

130. The following apparatus is much more suitable for all the experiments on combustion and the products of combustion described in this section.

The apparatus consists of a combustion tube, A, figure 17; one or more absorption tubes, B, and our aspirator, described El. Phys., 136, 137.

The combustion tube is of glass, from 3 to 6 mm. internal diameter, and at least 1 decimeter long. It may be gently bent, as the figure shows. The combustible is placed in the middle of this tube, and ignited by a hot wire (P) or by heating the tube from without (C, S).

The absorption tube consists of a common test tube closed by a stopper through which pass two glass tubes as shown in the figure. The glass tube connected with the

combustion tube by a rubber tube passes to near the bottom of the test tube; the other glass tube, connected with the aspirator or with the next absorption tube, passes but just through the stopper.

By successively placing thin square boards under the first flask of the aspirator, a flow of air is kept up through the apparatus precisely as rapid or slow as may be required. The state of combustion in the tube, A, indicates whether the current of air should be accelerated or retarded.

In these experiments it is best to use two aspirator tubes, the first being dry, the second containing some water. In this way the combustion of as much as one decigram may be safely performed by the student, and enough of the product of combustion will be shown free in the first absorption tube, and in combination with water in the second.

131. The high combustibility of phosphorus permits us to make use of phosphorus for the analysis of atmospheric air. About $\frac{1}{2}$ gram of dry phosphorus is placed on an iron dish (sand bath without sand) supported on a tripod under a bell glass, standing in a large vessel with water. The phosphorus is ignited with a hot wire, introduced through the tubulature of the bell glass; as soon as ignited, the wire is withdrawn, the tubulature closed by a glass stopper. The combustion will cease when there is no more oxygen in the bell glass; the unburnt phosphorus will remain. The bell glass will be filled with white vapors of phosphoric oxide (mainly). In about an hour they will have dissolved in the water.

The level of the water will be observed to have risen about one-fifth up the bell glass. Furthermore, a burning taper introduced through the tubulature, will immediately be extinguished in the residual gas. This gas, thus unfit to support combustion, is called nitrogen.

If a volume of oxygen, equal to the one-fifth volume lost, be added again to the nitrogen, a mixture will result perfectly identical with the air originally used.

Accordingly it is demonstrated, that atmospheric air is a mixture of $\frac{4}{5}$ nitrogen and $\frac{1}{5}$ oxygen.

132. All combustions going on in the air are due to the oxygen in the same. But in order to bring the necessary volume of oxygen to the fire by the draft of our fireplaces, we must supply at least five times as great a volume of air. The heating of the remaining nitrogen—even if all the oxygen be consumed—constitutes one of the wastes of fuel which it is impossible to remedy. Even if pure oxygen could be obtained for our furnaces, we would not be able to use it, because the iron fireplace would then burn even more brilliantly than the fuel in the same. See 100.

We shall in the third volume (*C o s m o s*) demonstrate that animal life is chemically a process of combustion. If in breathing we inhaled pure oxygen instead of the common air (oxygen diluted in four times its volume of nitrogen) we would very rapidly die of fever. Pure oxygen thus is a poison; but atmospheric air, containing 20 per cent of oxygen, is absolutely essential to life.

133. If a small piece of sulphur is burnt in a common flask, we shall notice a pale blue flame and the so-called odor of sulphur. The latter is exclusively* due to the gaseous product of combustion of sulphur. This product is usually termed sulphur di-o x i d e.† It is a colorless gas, distinguished by the odor of burning sulphur. One cc. of the gas weighs 2.861 mgr. By cooling this gas to 18 degrees, it liquefies.

*For a solid, which like sulphur does not volatilize at common temperatures, cannot possess any odor.

†Because theory shows that 2 particles of oxygen have combined with each one particle of sulphur.

134. If now a little water is added to the flask, the gas will soon dissolve, especially upon some agitation. The solution resulting is also an acid, because it reddens blue litmus paper; (see 129). It is called sulphurous acid. It bleaches vegetable colors, and is extensively used on that account. The litmus paper is first reddened, then bleached.

Sulphurous acid is evidently also a ternary, composed of hydrogen, oxygen, and sulphur. Since S is the negative, O the intermediate (combined with S in the sulphur di-oxide, and with H in the water), the scientific name of this acid must be hydrogen sulphite, or H S-ite.

This solution will not bear evaporation. By evaporation it again is dissociated into its constituent binaries. Thus by mixing or solution :

Hydrogen Oxide + Sulphur dioxide gives Hydrogen sulphite; but again by heating,

Hydrogen sulphite gives Hydrogen oxide + Sulphur dioxide.

The ready dissociation of this acid should be constantly kept in mind.

135. If, however, the sulphurous acid is left exposed to the air, it will soon stand evaporation without giving off sulphur dioxide; but it will then no longer possess bleaching properties. Hence it is no longer sulphurous acid; by proper experiments it has been demonstrated to have taken up more oxygen from the air. This fact can also be proved by the change taking place rapidly, if air is blown through the sulphurous acid. Hence the hydrogen sulphite has become hydrogen sulphate, or H S-a te. Evaporation of the dilute acid obtained above yields a strong acid identical with the well-

known sulphuric acid of commerce.* Accordingly sulphuric acid is hydrogen sulphate.

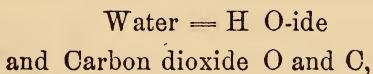
More easily the addition of oxygen is accomplished by holding a shaving, moistened with strong nitric acid, into the flask containing the sulphur dioxide and water, before shaking and mixing. See above, 133, 134.

136. A piece of charcoal burnt in a dry flask (see 129) or much better in the apparatus, 130, a colorless gas will result, destitute of odor. This oxide of carbon is called carbon dioxide.† It is heavier than atmospheric air, one cubic centimeter weighing 1.967 milligrams. It can be condensed to a liquid by pressure at all temperatures below 31° . By rapid volatilization of this liquid some of the dioxide solidifies to white snow-like crystals.

Since this gas is colorless and odorless, we require some simple test to prove its presence. Lime water—the clear filtrate from slaked lime soaked in water—becomes turbid when brought into this gas, as may be exhibited by using a rather wide tube as pipette, and holding this pipette with lime water into the above flask filled with carbon dioxide. The lime water will quickly become quite turbid or milky.

This gas is, of course, produced in all our fireplaces where carbon or carbonaceous fuel is used.

137. By pouring some water into the flask filled with carbon dioxide (136) and shaking, the gas will be absorbed. Hence we have



*This acid, often termed oil of vitriol, is manufactured in immense quantities. By the burning of sulphur they obtain sulphur dioxide, which gas is conducted into immense lead chambers where steam (water = H O-ide) and oxygen convert into Hydrogen Sulphate. The dilute acid of the chambers is evaporated in lead pans, and concentrated in platinum stills.

†In all older works on chemistry this oxide is termed carbonic acid: but this is a misnomer, the gas has no acid properties whatever. An acid results when the gas is combined with water. See 137.

giving a ternary compound of H, O, and C, and called Hydrogen Carbonate; abbreviated H C-ate. This ternary has also acid properties, and therefore is correctly called Carbonic Acid.

It is now manufactured on a large scale in a rather concentrated form by saturating water with the carbon dioxide gas under pressure at the freezing point (the vessel being placed in ice). This solution of carbonic acid is known as soda water.

138. Besides the above acids, the synthesis of which has been given, a great many other acids are more or less generally used. In the subsequent their composition will be established when their methods of preparation will be described. Here it may be sufficient to indicate their composition by the scientific name added to their common or vulgar name :—

VULGAR NAME.		SCIENTIFIC NAME.
Nitric	acid.	Hydrogen Nitrate.
Chloric	"	" Chlorate.
Boracic	"	" Borate.
Silicic*	"	" Silicate.
Arsenious	"	" Arsenite.
Arsenic	"	" Arsenate.
Chromic	"	" Chromate.
Manganic	"	" Manganate.
Permanganic	"	" Permanganate.
<hr/>		
Hydrochloric	"	" Chloride.
Hydrobromic	"	" Bromide.
Hydriotic	"	" Iodide.
Hydrofluoric	"	" Fluoride.

*Not to be confounded with Silicon oxide, commonly but incorrectly called silicic acid. Compare foot note to 136.

VULGAR NAME.	SCIENTIFIC NAME.
Hydrocyanic acid.	Hydrogen Cyanide.
<hr/>	
Hydrofluosilicic “	“ Fluosilicate.
Hydroferrocyanic “	“ Cyanoferrate.
Hydroferricyanic “	“ Cyaniferrate.*
<hr/>	
Acetic “	“ Acetate.
Oxalic “	“ Oxalate.
Tartaric “	“ Tartrate.

139. If a small piece of potassium is burnt in the combustion spoon† of the flask 129—all being perfectly dry—the purple flame will be seen quite beautifully, the flask will be partially filled with white fumes (because the metal is so volatile) and a whitish (or yellowish) residue will remain in the spoon. This compound is evidently Potassium Oxide; abbrev. Ka O-ide.

Potassium oxide is also exceedingly soluble in water; if the solution is evaporated to dryness, the oxide does not reappear, but a substance containing hydrogen as well as oxygen and potassium remains.

Since now potassium is the most electro-positive of all elements, oxygen the intermediate, hydrogen ought here to be considered as electro-negative; hence this new binary must be called Potassium Hydrate; abbrev. Ka H-ate.

It is not an acid, for the blue litmus paper is not reddened by it. But if a red litmus paper is dipped into the solution of this new body, we see the red paper turn blue again. Potassium Hydrate accordingly acts in a manner exactly the reverse of the acids. It is called a

*Strictly the last two acids should be distinguished as hydrous and hydric cyanoferrates; but the above given names more nearly conform to the vulgar ones in use.

†Better in the glass tube, 130. No absorption tube nor aspirator is required.

base. Its taste* is also quite different from what we call acid, or sour. Sodium yields in the same manner sodium oxide and the base sodium hydrate.

140. The common aqua ammonia also turns red litmus paper blue; it is also a base, and according to its composition it is termed ammonium hydrate. Ammonium has been found to be a compound of nitrogen and hydrogen, acting, under most circumstances, as if it were an element; it is therefore termed a compound radical, and designated by the symbol Am. Ammonium hydrate thus may be abbreviated Am H-ate.

But if aqua ammonia is heated, it dissociates into water and a colorless, very pungent gas, called ammonia, which passes off. This gas is absorbed with great avidity by water, reproducing the aqua ammonia. One cubic centimeter of gaseous ammonia weighs 0.763 milligrams. It has been condensed to a liquid by a pressure of about 7 atmospheres at common temperatures.

How ammonia and ammonium hydrate are obtained in immense quantities will be shown further on.

141. If limestone, marble or calcite crystals, are heated intensely in a glass tube communicating by a rubber tube with any apparatus for the collection of gases (El. Phys., 127), we shall see this receiver gradually fill with a colorless gas. Upon farther investigation this gas proves to be carbon dioxide; (see 136).

The white mass remaining in the tube will be recognized as burnt lime or quick lime; it has been found to be the same substance which results when the metal calcium is burned. Accordingly, the white residue is Calcium oxide.

Hence limestone, marble, or calcite dissociate at a bright red heat into calcium oxide and car-

*All these bodies should be tasted in minute portions much diluted with water. In fact, the student better abstain from tasting any of the chemicals, except especially requested to do so by a competent teacher.

bon dioxide. Therefore, the above common substances—limestone, marble, calcite, are calcium carbonate according to chemical nomenclature; see 125. Abbreviated Ca C-a t e.

142. Quick lime, that is, calcium oxide, absorbs water with great avidity, evolving much heat thereby, precisely as in the case of potassium oxide (139).

The resulting calcium hydrate is commonly known as slacked lime. It is but sparingly soluble in water; one cubic centimeter of water (1 gr.) dissolving only $\frac{5}{4}$ mgr. of the hydrate. The clear solution resulting is called lime water; it is a solution of calcium hydrate.*

143. Barium hydrate and strontium hydrate are obtained in a similar manner from their carbonates, which also occur as minerals. But these two hydrates are much more soluble in water, than calcium hydrate.

144. No other hydrates can be obtained by the means now described; because all other oxides are insoluble in water. For example, a short piece of magnesium wire burnt gives magnesium oxide; but this is not dissolved in water; after filtration, the oxide is found unchanged on the filter paper (El. Phys., 154).

We shall afterwards learn how the hydrates of these insoluble oxides can be prepared, by making use of the fact that these hydrates are also insoluble in water.

145. The soluble hydrates, especially those of the ka-loids, are often spoken of as Alkalies, also caustic alkalies. All hydrates are frequently termed bases.

*The student may intensely heat about half a decigram of calcite on platinum foil by means of the blow-pipe directed obliquely against the foil from below upwards. He will then obtain burnt lime, which when cold will hiss with a minute drop of water, and form slacked lime, producing a blue spot upon red litmus paper. By adding sufficient water to it in a test tube, lime water is obtained.

If the calcite is carefully weighed on the foil, before and after ignition, it will be found to lose nearly one-half of its weight by ignition. Hence nearly one-half of calcite is carbon dioxide, and somewhat more than one-half is calcium oxide.

146. It will be noticed that hydrogen is a component element both of the acids and of the bases; but that in the acids hydrogen is electro-positive as compared to the metalloid elements S, P, C; while in the bases hydrogen is electro-negative in reference to the metallic elements K, Na, Ca, Ba, etc. Accordingly we have the following definitions and additional rules in chemical nomenclature:

An acid is a compound containing hydrogen as the electro-positive element; usually combined with metalloids.

A base or hydrate is a compound containing hydrogen as the electro-negative element, usually combined with a metal and oxygen.

147. Acids turn blue litmus paper red; bases or hydrates turn red litmus paper blue—but only if these compounds are soluble in water. Hence the above definitions embrace many more compounds than could be recognized by litmus paper as bases or acids. But between the extreme action of potassium hydrate and sulphuric acid on the test paper, we have actually many gradations—many substances, not acids nor bases according to the definition turning the litmus colors. Hence, in the future we shall use the terms acid and base exclusively in accordance with 146. Whether hydrogen is electropositive or electronegative in these compounds is decided by electrolysis (see 105).

148. Even when bases and acids are mixed, the base is found at the electronegative pole, and thus proves itself electropositive, while the acid, in the same manner, appears at the positive pole, and thus is electronegative.

149. In some respects, tincture of cochineal*

* Cochineal warmed with dilute alcohol and filtered.

is preferable to litmus paper or litmus solution. For the ruby color of the tincture changes to purple by soluble hydrates, and to orange by acids. One drop of the tincture is sufficient to tinge 20 to 50 cc of the solutions of hydrates or acids. In general, liquids which do not change the ruby color of cochineal tincture are said to have a neutral reaction; if changed to orange, they are said to have an acid reaction; if changed to purple, they are said to have an alkaline reaction.*

150. If we now carefully add a dilute solution of the acid, drop by drop, from a pipette to a cubic centimeter of a solution of a hydrate, tinged purple by cochineal tincture, we will, after some time, see the color turn ruby-red, and by the next drop, to orange.

When ruby, the solution was neutral (149), the opposite action of acid and alkali exactly balancing one another. The number of drops required to produce this neutralization will, for the same solution of acid and base, be found to be constant. That is, base and acid neutralize each other in fixed proportions, which are to be determined by experiment.

It is of course necessary to stir, or better, to shake the liquid after the addition of each new drop, in order to distribute it evenly through the liquid. Besides, it is often advisable to add some water to the cubic centimeter of solution to be neutralized.†

*The same terms are also applied to the corresponding deportment towards litmus paper or litmus solution.

†Instead of counting the number of drops, it is better to measure the volume of acid used, if an apparatus for this purpose be at service. Mohr's Burette is the best apparatus for accurately measuring the amount of acid used. It consists of a wide glass tube, graduated to cubic centimeters and tenths (or fifths), drawn out to a narrow tube below. On this a rubber tube fits, kept closed by a brass spring clamp; the lower end of the rubber is provided with a glass jet. Fig. 18.

The burette is supported vertically, filled with acid up to the zero mark. It is sufficiently large for students' use if it holds 25 cc.

The vessel (beaker) containing the alkali is held in the right hand, and stirred (describing a horizontal circle with the right hand). The buttons of the spring

151. If the solution resulting by the neutralization of, for example, potassium hydrate by hydrogen sulphate, is properly* concentrated and left to cool, fine crystals will form, identic with the crystals of potassium sulphate described in El. Phys. 182.

If the evaporation be continued till dryness, the same substance, but imperfectly crystallized, will remain. Nothing but water will pass off, proved, if required, by evaporation of the solution in a small distilling apparatus.

Accordingly, we find that potassium hydrate and hydrogen sulphate give, upon neutralization, potassium sulphate and water. The water may therefore be considered as hydrogen hydrate, or the ternary H, O, and H; this is in accordance with the fact, that the volume of hydrogen is twice as great as the volume of oxygen (102).

Abbreviated by the use of the symbols, the above chemical process of neutralization may be written —



That is, the electropositives, Ka and H, have changed place; this is called double decomposition.

152. The mutual chemical action of compounds upon one another is usually called a reaction. It conduces to clearness if the reaction is represented in diagrams. The simplest representation of the reaction taking place when potassium hydrate (Ka H-ate) is neutralized by hy-

clamp are constantly between the thumb and first finger of the left: a gentle pressure will cause one drop to flow out.

When the color has changed, read the burette; it will show the number of cc used for neutralization.

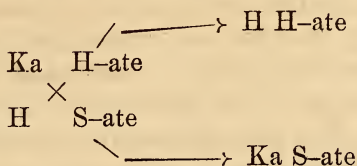
It is best to add another cc of alkali to the beaker, and repeat the neutralization. Five such experiments will give a mean value very accurate.

By using two burettes,—one for acid and the other for the base,—these experiments may be performed with greater rapidity, and base and acid may be alternately neutralized. This forms also a good lecture experiment.

The solutions for students' use should contain only about 2 or 3 centigrams of the above substances to the cubic centimeter.

* Until a glass rod, moistened with the solution, becomes covered with a crust of crystals soon after being taken out of the solution.

drogen sulphate (H S-ate) is, according to the preceding:



On the blackboard, these arrows should be drawn out in full.

153. If additional demonstration is required for this mutual decomposition, it may be obtained as follows:—

A drop of the solution of Ka H-ate remains clear upon the addition of a drop of Ba H-ate; but a drop of solution of H S-ate, as well as a drop of the resulting Ka S-ate, becomes turbid. Hence, the resulting Ka S-ate contains the sulphur compound of H S-ate.

Again: Ka H-ate, on a clear platinum strip (see 27), tinges the flame purple. So does the resulting Ka S-ate, but not the distillate H H-ate. But the purple flame is characteristic of burning Ka. Hence, the resulting Ka S-ate does indeed contain the Ka.

153. Compounds, binaries, or ternaries, not containing hydrogen, are called salts. Thus, Ka S-ate, Ca C-ate are salts. This completes the nomenclature supplemented in 146. We unite the terms acid, base, and salt in the following scheme:—

NAME.	BINARY.	TERNARY.	HYDROGEN.
Acid	H ν -ide	H ν -ate	Positive.
Salt	π ν -ide	π ν -ate	None.
Base	π H-ide	π H-ate	Negative.

154. In the act of neutralization, much heat is usually produced, as will have been noticed above. That is, the salt (and water) results from double decomposition of acid and base, because the latter occupy a higher chemical

level. The process in double decomposition is the same in kind, as the flowing of water down a slope.

Inversely, in order to reproduce acid and base from a salt, we have to apply an amount of heat (or mechanical work) equal to that produced in the formation of the same salt. The galvanic current is usually the simplest and most direct form of mechanical work applicable for the reproduction of acid and base from the salt and water; the base appearing at the negative pole, the acid at the positive pole. This fact may be shown by tinging the solution either with cochineal or litmus (105).

155. In addition to the above, the following quantitative experiments on combustion may be performed by the student:—

Combustion of carbon. Weight of product of combustion (carbon dioxide) per gram of carbon burnt. Use apparatus, Fig. 17, described in 130. Weigh combustion tube A with charcoal before and after combustion; difference, equals amount of carbon burnt. One decigram is quite sufficient if the balance weighs to the centigram. Use an absorption tube containing coarse fragments of pumice, moistened with potassium hydrate, which absorbs completely all carbon dioxide passing over it. Weigh absorption tube before and after the experiment; the increase in weight is the weight of the carbon dioxide produced in combustion. Divide the latter by the first weight, and the fraction—

$$\frac{\text{carbon dioxide}}{\text{carbon}} =$$

the proportion sought.

After use, close the glass tubes of the absorption tube by minute corks—or the rubber attachments by glass rods.

156. The same experiments may be made with sulphur; but a separate combustion and the absorption tube with potassium hydrate should be exclusively reserved for the combustion of sulphur.

157. The products of combustion of any flame may also be determined in this manner. Combustibles burning with flame contain hydrogen besides the carbon; compare 127. Hence, they produce water, as well as carbon dioxide, in combustion.

Water is absorbed by concentrated sulphuric acid, or by fused calcium chloride. The apparatus should then be arranged thus: The flame burning in a sufficiently wide tube (a funnel will do pretty well), attached by a rubber tube to the water absorption tube (containing concentrated sulphuric acid or pumice); this tube is connected with the absorption tube for carbon dioxide (described in 155); the latter is connected with the aspirator.

Loss in weight of the candle or lamp gives the amount of combustible consumed = A; increase of water absorption tube gives amount of water formed = B; increase of carbon dioxide absorption tube gives amount of this gas produced = C.

158. By burning hydrogen in this manner, it has been found that 1 of hydrogen gives exactly 9 of water; also, by burning pure carbon, it has been found that 1 of carbon gives exactly $\frac{11}{3}$ of carbon dioxide. Hence, the above experiment (157), if made with sufficient care, serves as an elementary analysis of the combustible used. For an amount of water = B required $\frac{1}{9}$ B of hydrogen; the amount C of carbon dioxide required $\frac{3}{11}$ C of carbon. Hence, in A of the combustible were contained $\frac{1}{9}$ B of hydrogen and $\frac{3}{11}$ C of carbon. The remainder is put down as oxygen, if the combustible was properly dry.

159. By gently exhaling through these two absorption tubes—the water absorption tube nearest the mouth—the weight of water and carbon dioxide exhaled in one respiration can be readily determined, if the balance weighs to the centigram. If the air passing from the carbon dioxide absorption tube is collected (El. Phys. 127) and

measured, we obtain the amount of water and carbon dioxide of the exhaled air per litre.

That the exhaled air contains carbon dioxide is also readily proved by passing the exhaled air through lime water (136).

160. In "cosmos," it will be more completely shown that animal life is, chemically, a process of combustion. If a large volume of atmospheric air—about 10 litres—is slowly drawn through the above two absorption tubes, the amount of water and carbon dioxide in the same can be determined by weight. The amount of water varies greatly. The amount of carbon dioxide is about 4 to 8 volumes (gas) in 10,000 volumes of air. This is the same as about 6 to 10 grams of carbon dioxide in 10,000 grams of air.

CHAPTER VI.

CHEMICAL PROCESSES.

I. Reactions.

161. We shall first consider the chemical processes in general, and thereafter add a few examples from the wide field of technical chemistry, especially so far as the processes can be carried on by the student with small amounts of material.

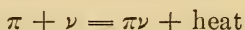
We may distinguish three kinds of chemical processes; namely: constructive, exchanging, and destructive processes. These may also be designated as descending, undulating, and ascending processes.

Synthesis is the simplest descending process, matter descending under the evolution of heat from a higher to a lower level. Dissociation and electrolysis are simple ascending processes, matter being lifted up by the application of heat or mechanical force to higher levels. Finally, in double decomposition, matter does not produce very much heat, nor revolve very much; such processes may therefore be considered as undulating.

Synthesis is also constructive, building up more complex forms of matter from less complex materials; carbon and oxygen uniting, bring the resulting more complex material carbon dioxide to occupy a lower level (98). In like manner, the ascending processes are destructive, in regard to the constitution of the materials; the more

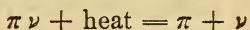
complex mercuric oxide is destroyed, as by the application of heat it rises to a higher level by dissociation into the simple substances mercury and oxygen.

162. In synthesis we have always a substance electropositive π in reference to the other substance ν wherewith it combines. In this process we have —

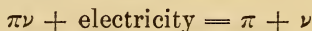


Example: $\pi = \text{C}$, and $\nu = \text{O}$, the combustion of carbon in oxygen; then each gram of carbon produces 8,000 calories of heat, equivalent to 3,434,000 gram-meters of mechanical work (compare 47 and 86).

In dissociation we have the reverse: —



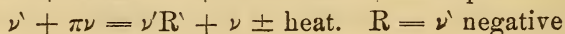
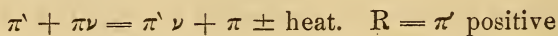
If the above carbon dioxide is to be decomposed into its elements, it has to be passed through a narrow platinum tube intensely heated. Instead of heat, we can use any other mechanical force, such as electricity —



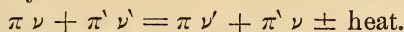
This constitutes electrolysis; for an example, see the decomposition of water (102).

163. Undulating or exchanging processes take place between two substances of which at least one is not an element. These processes are more commonly termed chemical reactions. We distinguish, according to the above, especially two reactions; namely: those between an element and a compound, and those between two compounds.

Reactions between any element R and any compound $\pi\nu$ are called substitutions, if R takes the place of one of the elements of the compound. The element takes the place of either π or ν , according as R is either relatively positive or negative. The general formula for these reactions are: —



Reactions between two compounds $\pi\nu$ and $\pi'\nu'$ are termed double decompositions, and may be represented by —



Here we write \pm heat, because in some reactions heat is produced, in others, heat is required. Of course, heat may be replaced by its equivalent in mechanical work (see 80).

164. Quite frequently several of these processes are going on at the same time in the same vessel. Such processes may be termed complex processes.

Many of the great staples, now necessities of life, are the result of a complex process, so far as they result from a series of processes carried on, one after the other, in a chemical laboratory.

In this sense, animal and vegetable life are complex processes; however, we shall, in "Cosmos," learn that the vegetable processes are ascending or constructive, while the animal processes are descending or destructive.

165. The amount of heat evolved or consumed in these varied processes can be determined by means of the calorimeter (see 46). The work of determining these quantities is now carried on with great diligence in various quarters. The fixed proportions in weight obtaining in these processes between the different materials have already, in general, been determined. See 182. Both the quantitative determinations in regard to mass (weight) and motion (heat or force) must be left for consideration in the Principles of Chemistry.

We shall now proceed to the consideration of individual examples of these processes.

II. Synthesis.

166. Numerous examples of synthesis have already been given in the preceding, especially the combustion of certain elements (H, P, S, C, Ka), and the uniting of the

oxides produced with water (129, a. f). See, also, the synthesis of mercuric iodide, 101.

Zinc is burnt on a large scale in furnaces; the resulting zinc oxide (flowers of zinc) is used as a paint, under the name of zinc white. Lead oxide is also manufactured by burning metallic lead; the most common is the yellowish litharge. By continued exposure to the air at high temperatures, litharge takes up more oxygen, and becomes red lead.

The student may prepare these oxides by heating a small quantity (1 cgr.) of the metals in charcoal, on the blow-pipe flame. Observe the changing colors of zinc oxide upon repeated heating and cooling. Also add a drop of cobalt solution to the zinc incrustation, and ignite again; the green pigment resulting from the synthesis of zinc oxide and cobalt oxide is used as a green paint.

167. Many oxides are formed by an indirect synthesis, two or more combined oxidable elements being oxidized at the same time. Thus, by the combustion of our common combustibles, the oxides of hydrogen (water) and carbon are formed at the same time. Compare 157.

In the common metallurgical process, called *roasting*, oxides are formed in the same manner. Common pyrite (El. Phys., 165) intensely heated in a glass tube, open at both ends, (28) yields sulphur dioxide (see 133), and a red oxide of iron.* Hence, pyrite contains iron and sulphur; it is iron disulphide. Immense quantities of pyrite are thus roasted in furnaces, to manufacture sulphuric acid (see 135).

The white arsenical pyrite, heated in the same manner, yields, besides the iron oxide and some gaseous sulphur dioxide, also much of a white sublimate of arsenious oxide, commonly called white arsenic, or ratsbane. On a large scale this oxide is manufactured

*From this oxide the metallic iron is extracted, by heating a mixture of the oxide with soda on charcoal in the reducing blow-pipe flame.

by burning the arsenical pyrite (commonly called *mis-pickel*) in a furnace, to which a series of chambers is attached for the deposition of the white arsenic, while the sulphur dioxide escapes into the air.* Accordingly, *mis-pickel* contains iron, sulphur, and arsenic. Most of the ores containing sulphur and arsenic have to be freed from these elements by roasting before the metal can be extracted.

168. At times, only some one of the elements is oxidized in such indirect combustion. Thus, most of the lead, as smelted from its ore, contains a small quantity of silver. Since the lead is oxidable (combustible), but the silver not, the latter will remain if the lead is burnt away. Argentiferous silver is heated intensely in a strong current of air; the lead oxide formed fuses, partly runs off, and partly soaks into the porous hearth; finally, the pure silver remains. This metallurgical process is called *cupellation*.

By heating a small piece (5 cgr.) of richly argentiferous lead on a bone-ash *cupel* in the oxidizing flame of the blow-pipe, the student may, on a small scale, imitate the process of cupellation.† The blow-pipe assay of silver consists in the cupellation of the argentiferous lead obtained from the alloy or mineral by scorification.*

169. Many iodides, bromides, chlorides, sulphides, etc., are also obtained by direct synthesis from the elements. See 101.

By fusing metals with a proper proportion of sulphur, many sulphides may be readily obtained; especially Fe,

* It will be noticed that the apparatus used for manufacturing purposes is exactly represented in its different parts by the different portions of the glass tube above used.

† White burnt bone pulverized, and the fine bone-ash, either packed firm in a cavity of the charcoal, or better, formed in Plattner's *cupel-iron*.

* About 2 cgr. silver coin alloy fuse together with 1 dgr. pure lead (test lead). The resulting globule cover with about an equal portion of borax; heat in oxidizing flame on charcoal until but a small metallic globule remains. This globule is *cupelled*.

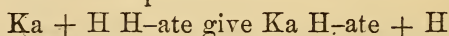
Cu, Sn, As. By heating charcoal in a tube red hot, and passing vapors of sulphur over it, carbon bisulphide is formed, and may be obtained in the liquid form by condensing its vapor. Carbon burns with sulphur precisely as with oxygen.

170. The black iron sulphide, properly called ferrous sulphide, is obtained by fusing a mixture of 1 sulphur and $1\frac{1}{2}$ iron. It is much used in the laboratory, because with acids it evolves the useful sulphuretted hydrogen gas. The student may prepare a small quantity of ferrous sulphide by fusing about 5 cgr. of the mixture in a closed glass tube. By dipping the hot extremity of the tube into water in a glass, the tube cracks, and the sulphide may be taken out. If put into water, and a drop of sulphuric acid is added, the sulphide will evolve the sulphuretted hydrogen gas, easily recognized by its offensive odor (of rotten eggs).

III. Substitution.

171. The general formula of substitution has already been given in 163. We may therefore pass directly to the exemplification of some of the kinds of substitution most commonly practiced.

172. Many electropositives (especially metals) may be substituted for hydrogen in acids, by dissolution. Thus, the kaloids and calcoids displace hydrogen, even in water at common temperatures :

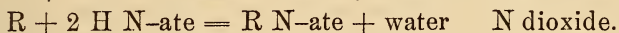
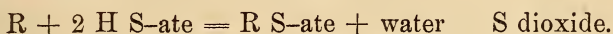


The metals Mg, Zn, Fe, require a dilute acid in order to displace hydrogen, especially dilute sulphuric or hydrochloric or nitric acids :



The metals Cu, Hg, Ag, do not displace the electropositive H in dilute acids; but concentrated sulphuric or nitric acid are dissociated, especially upon heating, and yield the corresponding sulphate or nitrate, together with sulphur dioxide or nitrogen dioxide — both gases

readily recognized by their pungent and peculiar odor. The reactions may be expressed thus:



The nitrogen dioxide gas oxidizes in contact with the air to the characteristic red vapors always observed when nitric acid is dissociated.

Gold and platinum are not dissolved by any of the above acids, taken singly; but they are dissolved, when heated, in a mixture of nitric and hydrochloric acids. This mixture is called *aqua regia*. It yields the chlorides of the above metals.

173. Accordingly, we distinguish the following four grades of solubility for metals: —

1. Sol. in water: Kaloids, *Ka* and *Xa*.
2. Sol. in dil. acids: *Mg*, *Zn* (*Pb*), *Fe*.
3. Sol. in conc. sulphuric or nitric acids: *Cu*, *Hg*, *Ag*.
4. Insol. in single acids, sol. in aq. reg.: *Au*, *Pt*.

Also, *Sn* and *Sb* are oxidized by strong nitric acid, but not dissolved.

For students' practice, about one centigram of either of these metals may be dissolved as indicated. Thus, may be prepared: —

In crystals: Hydrated *Mg S-ate* (epsom salt, *El. Phys.*, 185); hydrated *Fe S-ate* (green vitriol); *Pb N-ate*; *Hg-ic N-ate* (by heating); *Ag N-ate*.

Not readily crystallized: *Mg*, *Zn*, *Fe*, *Au*, *Pt*, chlorides.

Always observe the gas evolved; verify that from dilute acids, *H* is evolved; from concentrated *N-acid*, red fumes; from concentrated *S-acid*, sulphur dioxide. Use water-bath, except for the salts of *Au*, *Pt*, when the sand-bath is advisable. Never use more than 2 cgr. of metal; add acid, drop by drop, as required, never adding a new drop until called for by the cessation of the reactions, and

the continued presence of the metal. From the crystals formed, try to reproduce the metal in the reducing flame on charcoal before the blow-pipe. See 175.

174. From the preceding, it will appear that the order of solubility of the principal metals is as follows: most *Ka*, *Na*, *Mg*, *Zn*, *Fe*, *Pb*, *Cu*, *Hg*, *Ag*, *Au*, *Pt*, least

If, therefore, any of these metals is placed in the solution of any of the metals less soluble, the latter will be reduced. Thus, *Ag* thrown into *Au* solution, will reduce the gold:

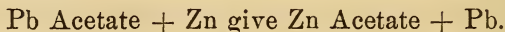


The most common case is—



This reaction you can verify by throwing any fragment of iron into a solution of copper; you will soon see the blue color of the copper solution fade and change into the green color of iron solutions, while metallic copper separates in the shape of the iron, especially if the copper solution was dilute. If the copper solution is not dilute and acid, the copper separates always as a brown powder, which, when pressed by the knife on paper, assumes metallic luster.

A dilute* lead solution, especially of lead acetate, deposits beautiful leaf-like crystals of metallic lead, if a brass wire to which a small piece of zinc is attached, is immersed into the solution, and the latter stoppered. A few cubic centimeters of solution in a minute vial are sufficient. This arborescent growth of lead crystals is often called the lead tree.



All these reductions of the less soluble metals from their solution are termed reductions in the wet way.

175. In the dry way, many metals can also readily be reduced from their compounds, by means of metals or metalloids more combustible.

*Containing but 1 or 2 cgr. in each cc. Solution cleared by acetic acid.

Of all the elements, carbon and hydrogen are the more combustible ones. Hence, carbon and hydrogen are, in high temperatures, powerful reducing agents. The cheapness of coal makes its application for the reduction of metals very nearly universal and exclusive.

Thus, all iron ores — at least, after roasting — are iron oxides. They are, in high furnaces, mixed with coal. The coal burns, partly at the expense of the oxygen of the iron oxide, which thus becomes reduced to metallic iron.* In like manner, zinc, lead, copper, are obtained from corresponding ores.

The student should practice such reductions by the blow-pipe on charcoal. A little soda is mixed with the ore, to facilitate the reduction. See 95; also, 25.

By passing hydrogen over the oxides of copper or iron, the oxide is also reduced to the metallic condition under the formation of water; thus:

Cu O-ide & H give Cu & H O-ide (water).

This experiment may also be performed by the student; the oxide to be reduced should be gently heated in a glass tube while the hydrogen gas is passed over it. For caution, 103.

176. Iron combines more readily with sulphur than lead, especially in higher temperatures. Hence, lead can be smelted from its ore — galena — (= lead sulphide), by throwing iron into the fused ore. Thus:

Pb S-ide & Fe gives Fe S-ide & Pb.

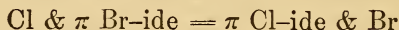
In a like manner, antimony is smelted from its ore, Sb S-ide.

These processes are readily exemplified by means of minute quantities heated in the glass tubes by the blow-pipe.

177. The substitution by means of an electronegative element is not so common as the above.

*Containing from 4 to 5 per cent. carbon, thus constituting pig iron, or cast iron. By burning the carbon out (Bessemer process, also, puddling process), steel (1 to 2 per cent. carbon) and wrought iron ($\frac{1}{2}$ per cent. carbon) is obtained.

The simplest case is the substitution of the chloroids, one for another. Bromine expels iodine; chlorine expels either iodine or bromine; thus:



The student should practice these substitutions in the following manner. To a drop of the iodide, or bromide solution in the test-tube, add about 0.5cc. of water; then two or three drops of carbon bisulphide, or chloroform; finally, a small drop of dilute chlorine water.* The chlorine displaces the I or Br, the latter being not very soluble in water, but readily soluble in the chloroform or carbon bisulphide, and are, upon shaking, transferred to the latter, which becomes tinged by the iodine (red) or bromine (reddish yellow) dissolved.

178. Chlorine also frequently displaces oxygen; thus:



If chlorine water is exposed to sunlight it is decomposed, yielding hydrochloric acid; thus:



Therefore, chlorine is a powerfully oxidizing agent, so that it is eminently applicable for disinfecting and bleaching purposes. The manufacture of bleaching powder (chloride of lime) and of bleaching solution (chloride of soda) depends upon this property. The chlorine gas, brought into contact with the calcium hydrate (slacked lime), yields chloride of lime; if passed into dilute sodium hydrate solution, the so-called Labarraque's solution of chloride of soda results. The process is not a simple substitution, but complicated by double decomposition; hence, it is not proper here to give further details. The resulting bleaching com-

* Chlorine absorbed in water; this solution keeps only in bottles covered with black paper; see 178.

pounds contain the chlorine in a more permanent form than the chlorine water; but the slightest amount of acid will set the chlorine free again.

On account of the deliterious effect of chlorine on the respiratory organs, these experiments should not be made by students in the general laboratory.

179. The oxidizing action of chlorine is also used for the manufacture of potassium chlorate. Into a concentrated, warm solution of potassium hydrate, chlorine gas is passed; soon crystals of potassium chlorate separate, while in the liquid remains potassium chloride. The process is rather intricate; the oxygen of the hydrate is concentrated in the chlorate, while the chloride retains the greater part of the potassium, and the hydrogen yields water.

180. By the oxidizing action of chlorine (or chlorine water) π -ous solutions may be converted into π -ic solutions. Compare 125.

Green vitriol gives a pale green solution of ferrous sulphate (5 cgr. in 1 cc. water suffice). Chlorine water added hereto gives a faint yellow solution of ferric sulphate, especially upon gently heating the same.

By a few precipitations (see 182) these two salts may be more readily distinguished. To a drop of the solution, placed on a glass plate, a drop of the re-agent is added; the precipitate stated below will then be observed:

RE-AGENT.	SOLUTION.	
	Ferrous.	Ferric.
Am Hydrate	Whitish, changes to green and brown.	brown.
Ka Cyanoferrate	no pr.	blue pr.
Ka Cyaniferrate	blue pr.	no pr.

Potassium permanganate is also a powerful oxidizer in the wet way. It changes ferrous salts immediately into ferric salts. Each drop of the permanganate

solution loses its beautiful purple color immediately in the ferrous solution; but when all of the ferrous salt has thus been oxidized to ferric salt, the next drop of permanganate added tinges the entire iron solution purple. To prevent the precipitation of some of the iron compound, it is best to add a few drops of pure sulphuric acid before adding the permanganate.

By means of a standard permanganate solution, the amount of iron in a ferrous solution can therefore be most readily determined by noting the volume of permanganate solution consumed.

181. Oxygen can replace sulphur. If sulphuretted hydrogen (see 170) is passed into common water — which always contains some air — the resulting liquid will soon become turbid, from the separation of minute particles of sulphur. The substitution taking place is



The same separation of sulphur constantly takes place near sulphur springs; the oxygen of the air taking the place of the sulphur in the hydrogen sulphide water. Hence, if sulphuretted hydrogen, *i.e.*: hydrogen sulphide, is to keep in solution in water, the water should, by boiling, be freed from all air before the gas is passed into it.

For the same reason, hydrogen sulphide in solution is a reducing agent; ferric solutions are reduced to ferrous solutions under the separation of water, the additional oxygen being taken from the ferric compound. Chromates are also reduced by hydrogen sulphide, the yellow color changing to green thereby.

182. By careful quantitative determinations, it has been found that the elements replace one another in fixed, invariable proportions. Thus: to displace one gram of hydrogen by potassium (see 172), requires 39 grams of potassium; 23 grams of sodium are required to displace 1 gram of hydrogen; hence, 23 grams of sodium, or 39

grams of potassium are equivalent to 1 gram of hydrogen.

By the substitution of iron for copper, etc. (see 174), it is found that 56 grams of iron are equivalent to 63.4 grams of copper; each of these quantities being equivalent to 2 grams of hydrogen, because 63.4 grams of copper can be replaced by 2 grams of hydrogen.

In the "Principles of Chemistry" these relations will be fully investigated. Here it must be sufficient to give an alphabetical list of the symbols of the elements, together with the so-called atomic weight of the element, determined mainly by ascertaining the relative quantity of the elements in substitution. The atomic weight of hydrogen is taken as unity, or $H = 1$; the weight of the smallest possible particle or atom of hydrogen is thus taken as the unit of the atomic weight. Hence, $Ka = 39$, signifies that one of the atoms of potassium weighs as much as 39 atoms of hydrogen.

183. TABLE OF ATOMIC WEIGHTS OF THE ELEMENTS:

Ag	108	Cl	35.5	Li	7	Rh	104
Al	27.4	Co	60	Mg	24	S	32
As	75	Cr	52	Mn	55	Sb	122
Au	197	Cu	63.4	N	14	Se	79.5
Ba	137	Fe	56	Na	23	Si	28
Bi	210	Fl	19	Ni	58	Sn	118
Bo	11	H	1	O	16	Sr	87.6
Br	80	Hg	200	P	31	Te	128
C	12	Ir	198	Pb	207	Ti	50
Ca	40	Io	127	Pd	107	Ur	120
Cd	112	Ka	39	Pt	197.4	Zn	65.2

184. The quantitative composition of a chemical compound can now be expressed by a chemical formula, consisting of the symbols of the constituent elements, each provided with an index, stating the number of atoms of the element contained in each atom of the compound. Thus, the chemical formula of water is H_2O ;

that is, each atom of water consists of two atoms of hydrogen and one atom of oxygen. Hence, by weight, 2 atoms = 2 of hydrogen, and one atom = 16 of oxygen, give one atom = $2 + 16 = 18$ of water. So, also, CaO_3C is the chemical formula of calcium carbonate; for it has been found that one atom $\text{Ca} = 40$, and three atoms O of 16 or 48, and one atom $\text{C} = 12$, constitute one atom of calcium carbonate, which, therefore, weighs $40 + 48 + 12 = 100$, or as much as 100 atoms of hydrogen.

As stated above, the full consideration of this subject, and especially the demonstration of the same, must be deferred to the principles. The following few examples may prove of interest:

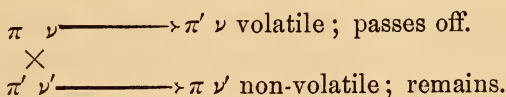
Hydrogen sulphate, $\text{H}_2\text{O}_4\text{S}$. Silver nitrate, AgO_3N . Barium chloride, BaCl_2 . Carbon dioxide, CO_2 . Mercuric oxide, HgO . Mercuric oxide, HgI_2 .

IV. Double Decomposition.

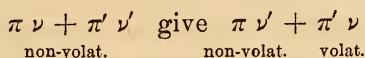
185. The general formula for double decomposition has been given already in 163. Accordingly, if two compounds $\pi \nu$ and $\pi' \nu'$ both decompose and interchange components, we shall have the new compounds $\pi \nu'$ and $\pi' \nu$; such a process is called double decomposition.

But when two compounds are mixed, we can, as a rule, not readily tell whether double decomposition actually takes place or not, unless some of the new compounds separate from the mixture. Such separation can only consist in volatilization or in precipitation.

If one of the new compounds is volatile, converted into a gas (if necessary, by means of some heat), we have a double decomposition by volatilization which may be represented in the following scheme:

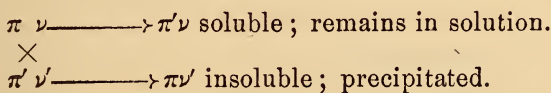


or,

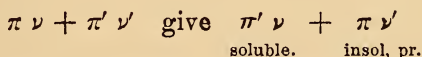


If one of the new compounds is insoluble, it will of course appear in the solid form, separating from the solution as fast as produced; such separation of a solid from a liquid we call precipitation, because, as a rule, the solid has a greater specific gravity than the solution, and therefore sinks to the bottom of the vessel as if it had been thrown down (precipitated).

The general formula for double decomposition by precipitation is



or,



It is of course highly important to observe especially the color of the precipitate, also its solubility in liquids other than the solution in which it formed. It is also important to ascertain whether further addition of the precipitant redissolves the precipitate formed or not.

186. To effect a complete separation in double decomposition by volatilization, the volatile compound has often to be expelled by the application of heat, and collected by cooling in a receiver; in fact, the volatile compound is distilled off. Therefore, the double decompositions by volatilization are, in such case, also termed double decomposition by distillation; or sublimation, in case the volatile substance solidifies.

If the volatile substance is a gas at common temperatures, no heat will be required. The gas will separate in

bubbles throughout the liquid as soon as mixture takes place. Such separation of a gas by double decomposition is called an *effervescence*.

The properties — especially color and odor — of the volatile substance should be carefully observed and recorded.

To effect a complete separation of the solid from the solution in case of double decomposition by precipitation, the entire mass is thrown on a washed filter (*El. Phys.*, 154), and after the liquid (the filtrate) has passed through the filter, the precipitate is washed by water (or some other liquid), and the washings running through a filter are collected in a separate vessel.

187. It will already be apparent that these two modes of double decomposition are of utmost practical importance. For any volatile compound can be prepared by double decomposition of the first kind; so, also, any solid, by expelling the volatile. Again: any insoluble compound can be prepared by precipitation; and any soluble compound by precipitating the insoluble from it by the same operation.

Also, in analytical chemistry, these operations are of the utmost practical importance, because the separated volatile or insoluble substance produced by the addition of a known compound, in most cases, can be readily identified, and thereby make known the other component.

The following practical examples will tend to make this subject better understood.

188. The more common acids may, in regard to their volatility, be arranged in the following order:

MOST VOLATILE.

1. H C-ate; dissoc. to carbon dioxide gas.
2. H S-ide; gaseous.
3. H S-ite; dissoc. to sulphur dioxide gas.
4. H Cy-ide; gas — exceedingly poisonous.
5. H Cl-ide.
6. H N-ate.

7. H Acetate.
8. H S-ate ; the most common.
9. H P-ate.
10. H Bo-ate.
11. H Si-ate ; dissociates to silicon dioxide, solid.

LEAST VOLATILE.

This is ascertained by heating the acids named.

189. Accordingly, by means of the most common acid, —H S-ate,— we can prepare all the more volatile (preceding) acids. The first four require no application of heat, because they* are gaseous at common temperature. The next three are prepared by the application of heat ; *i. e.*, by distillation. The following examples may be worked by the student, and written out as in 183 and 184 :

190. Na C-ate + H S-ate give Na S-ate + H C-ate ; but the H C-ate dissociates into water and carbon dioxide gas, which passes off (odorless, effervescence). If calcium carbonate is to be used, sulphuric acid will be found to work slow, because calcium sulphate is not very soluble ; hence, to dissolve Ca C-ate, take hydrochloric acid H Cl-ide, or nitric acid H N-ate ; thus :

Ca C-ate + H Cl-ide give Ca Cl-ide + H C-ate (dissoc*).

By weighing a light flask, loosely stoppered with cotton, and containing dilute hydrochloric acid (1 acid to 3 water), throwing into the acid a known amount (ca. 5 dgr.) of limestone successively in small pieces, waiting each time until the preceding piece is dissolved, also each time quickly replacing the cotton stopper to retain the moisture ; then the weight of the flask and contents, at the close of the experiment, is equal to its original weight plus the weight of limestone dissolved less the weight of carbon dioxide gas passed off. From these data, calculate the amount of carbon dioxide gas in one gram of limestone.

*Or their product of dissociation (see 1 and 3) ; which again, in water, reproduces the acid. Compare 131.

If you treat pure calcium carbonate, such as calcite fragments, in this manner, the balance will be calcium oxide. Compare 141.

191. The sulphites deport themselves precisely as the carbonates, except that the gas evolved has the odor of burning sulphur, because it is sulphur dioxide. For experiment, use sodium bisulphite.

192. By adding a drop of sulphuric acid to the water in a test tube containing a few small fragments of iron sulphide, the liquid will effervesce; the gas evolved possesses the odor of rotten eggs, and thereby is readily recognized (170). It is commonly called sulphuretted hydrogen, but its scientific name is hydrogen sulphide, as will be seen from the following:

$\text{Fe S-ide} + \text{H S-ate} \text{ give } \text{Fe S-ate} + \text{H S-ide}.$

See, also, 181.

193. A cyanide treated in the same manner gives an effervescence possessing the odor peculiar to peach blossoms; this odor is due to the highly poisonous gas evolved, which is hydrogen cyanide, commonly called hydrocyanic or prussic acid.

$\text{Ka Cy-ide} + \text{H S-ate} \text{ give } \text{Ka S-ate} + \text{H Cy-ide}.$

The student should operate only with exceeding minute quantities.*

194. Hydrogen chloride is evolved from sodium chloride (common salt) and sulphuric acid; a gentle heat may be applied. The gas is usually collected in water, and the aqueous solution resulting is commonly called hydrochloric acid.

$\text{Na Cl-ide} + \text{H S-ate} \text{ give } \text{Na S-ate} + \text{H Cl-ide}.$

The common, impure acid of the shops is called *mu-riatic acid*.

195. Nitric acid is distilled from sodium nitrate (Chili saltpeter) and sulphuric acid.

* In such case, but very little water should be used, because the gas is rather soluble in water.

$\text{Na N-ate} + \text{H S-ate}$ give $\text{Na S-ate} + \text{H N-ate}$.

The pure potassium nitrate (saltpeter) gives a purer product.

The common impure nitric acid is also called *aqua fortis*.

196. Acetic acid is commonly distilled from lead acetate (sugar of lead) and sulphuric acid :

$\text{Pb Acetate} + \text{H S-ate}$ give $\text{Pb S-ate} + \text{H Acetate}$.

A small quantity of the acetate heated in the test tube with a drop of dilute sulphuric acid, will yield the acid in sufficient quantity to be recognized by its odor.

197. The acids less volatile than sulphuric can, of course, not be prepared by sulphuric acid. But these acids are often used to produce the salts, by heating the acid with the corresponding sulphate.

Thus, copper phosphate will be left, if copper sulphate is sufficiently heated (ignited) with phosphoric acid :

$\text{Cu S-ate} + \text{P-ate}$ give $\text{Cu P-ate} + \text{H S-ate}$.

It requires a temperature of more than 200° to expel the hydrogen sulphate; the acid dissociates, forming white fumes. Since these fumes are exceedingly corrosive, the experiment should be made with minute quantities on the foil.

198. The silicate of any metal is prepared by igniting with silicic acid the salt of the same metal containing any volatile acid; such are, according to 188, the carbonate, sulphide, sulphite, etc., until sulphate, inclusive.

$\text{Cu S-ate} + \text{H Si-ate}$ give $\text{Cu Si-ate} + \text{H S-ate}$.

But since silicic acid dissociates into water and silicon dioxide at a low temperature, the latter may be used instead of the acid. Sand is a common form of impure silicon dioxide (silica).

199. The silicates most extensively manufactured are water-glass and glass.

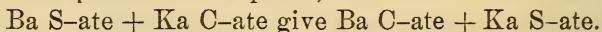
Water-glass is potassium or sodium silicate; obtained by fusing the corresponding carbonates with silica.

Common glass is double silicate of sodium and calcium, obtained by fusing soda (= sodium carbonate), limestone (= calcium carbonate), and silica together. But many other varieties of glass are in use. Flint glass is more lustrous, heavier, and less hard than other glasses, because it contains some lead oxide.

These silicates may be prepared by the student as beads on the platinum wire. The flint glass bead should be fused on charcoal, because it is liable to destroy the platinum wire.

200. Fluxing is the fusing of an insoluble compound with sodium or potassium carbonate; the resulting flux can be dissolved.

For example: barium sulphate is insoluble in all acids. When fused with potassium carbonate on the foil, a double decomposition takes place; thus:

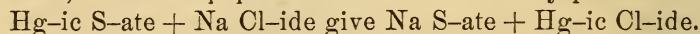


For when the foil is boiled with water, a solution is obtained containing Ka S-ate together with the excess of Ka C-ate used. The residue insoluble in water is Ba C-ate, and dissolves with odorless effervescence in dilute hydrochloric acid.

This operation is much used in chemistry.

201. Many other compounds are prepared by double decomposition in higher temperatures. We shall here mention only two examples.

Mercuric chloride, commonly called corrosive sublimate, is volatile; hence, it may be prepared by heating a small quantity of any chloride with any mercuric salt in a small tube. The resulting mercuric chloride will deposit as a white sublimate on the colder parts of the tube; hence its popular name. It is a deadly poison.



202. The volatile base ammonium hydrate (140) is prepared by heating any ammonium salt with any hydrate.

The student may add a drop of potassium hydrate to a

minute quantity of any ammonium compound (Am v-ate) in a test tube; he will then recognize the ammonia gas resulting from the dissociation (140) of the Am H-ate produced by its pungent odor, and by producing white fumes with a drop of a volatile acid brought near on a glass rod, or by turning moistened red litmus paper blue when held in the tube, but above the liquid.

Am v-ate + Ka H-ate give Ka v-ate + Am H-ate.
The Am H-ate dissociates, as stated, into ammonia gas and water.

203. Double decomposition by precipitation (184) enables us to prepare insoluble compounds. To be able to apply this method, we should first learn which compounds are soluble, and which are insoluble (in water, understood). The following will be verified by subsequent experiments, but should be carefully committed to memory:

1. SOLUBLE are (almost) all salts of the kaloids Ka, Na, Am, and hydrogen; also (almost) all nitrates, chlorates, acetates.

2. INSOLUBLE are all carbonates, phosphates, oxalates, except those of the kaloids; all sulphides, oxides, and hydrates, except those of the kaloids and calcoids.

3. INSOLUBLE are the sulphates of the calcoids (Ca, Sr, Ba,) and lead (Pb).

4. Ag, Pb, and Hg-ous chloride and iodide are insoluble; also, Hg-ic iodide.

204. For practice, the student should verify the above as far as convenience and time admit. Two modes of experimentation should be used alternately; first, the student should investigate the solubility of any given negative, such as the sulphates, chlorides, etc.; secondly, the student should investigate the solubility of the different salts of the same electropositive, such as lead, silver, etc.

Only one drop of the solutions is required, taken by means of a tube-pipette from the small reagent flask, Fig. 19, of about 15 cc. capacity. By means of cotton tied around the pipette, the bottle is quite sufficiently closed; only bottles containing corrosive acids require a piece of rubber tubing around the pipette.

The result may be observed either in test tubes, or on a glass plate; the latter method is the most convenient, except in cases when heat or additional solvents are to be used. The glass ware used should, of course, be clean; the plate should also be dry. All glass ware should be carefully cleaned before it is returned.

205. If the first method is used, and if the student is to verify the solubility of the compounds of the same negative, he receives a flask containing the potassium or sodium salt of this negative, and adds a drop from this to a drop from each of the solutions of Ca, Ba; Mg, Zn, Pb; Hg-ous, Hg-ic; Cu, Ag; Am, Fe-ous, Ni, Co; Al, Fe-ic, Cr-ic, Sn, As, Sb, Bi; each contained in a separate flask, each provided with pipette and cotton stopper. Also, a bottle containing dilute nitric acid.

The results are carefully entered in the journal; thus:

SOLUBILITY OF .. ν

Solution of ν used:

Sol. of π .	Result.
Ka N-ate
Ba N-ate
.....

The result should be stated concisely, but fully: whether precipitate forms, what appearance the same has, what color; also, whether soluble in dilute nitric acid, etc. The card or laboratory label accompanying each set will give any further special information required. It will be understood that a precipitate forms only if the substance is insoluble.

The reaction should be written out as exemplified in 184, in all cases where a precipitate forms.

206. The verification of the solubilities of the different compounds of the same electropositive (metal) is performed in the same manner. In this case, the one solution of the electropositive (usually nitrate) is accompanied with a set of the solutions of the Ka or Na salts of the principal acids named; thus: sulphate, chromate, phosphate, borate, oxalate; the hydrate, sulphide, chloride, iodide, cyanide (?), cyanoferrate, cyaniferrate.

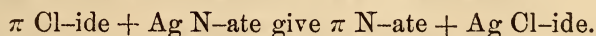
Otherwise, the work is precisely as in 205.

207. The student may, for 206, prepare the solution himself from the metal; only about 2 cgr. of metal is required. See 173.

It is also well to repeat some of the precipitations in a test tube, to filter through a minute filter inserted (without the aid of a funnel) in another test tube, to wash some, and finally to take the precipitate (with lowest part of filter) and heat it either alone or with soda on charcoal in the inner flame, in order to reproduce the metal (175).

By working several series of these simple exercises, the student will not only have become familiar with the deportment of the substances he handled, but also be able to understand many of the processes of chemical technics. He will furthermore comprehend by what means the presence or absence of the different elements in any given substance can be established, and often the amount quantitatively determined.

208. The amount of chlorine in any solution can thus readily be determined by completely precipitating the same with a silver solution (silver nitrate); for silver chloride is insoluble in water and in acids (203, 204).



If a drop of potassium chromate has been added to the chloride solution, the liquid will be tinged faintly yellow therefrom; as long as chlorine is present, it will be thrown

down by the silver solution as white silver chloride; but after all chlorine has been precipitated, the silver solution will form silver chromate, which is recognized by its red color. Hence, we know when the chlorine is all precipitated by the appearance of this red color.

A solution containing 3.042 mgr. silver in the cubic centimeter precipitates 1 mgr. chlorine by each cubic centimeter.

The student may determine the amount of chlorine in given salt solutions in this manner, using a Mohr's burette (see 150). The silver chloride produced must be returned to the teacher.

V. Complex Processes.

209. The processes of synthesis, substitution, and double decomposition are frequently combined, and again, at other times, are associated with dissociation or electrolysis. In larger and more advanced works on chemistry, many such complex chemical processes are described.

210. Such complex processes are especially frequent in the vital processes of plants and animals. In the substance of these living beings, a great multitude of different serial compounds have been discovered, and infinitely more have been artificially obtained from them by chemical processes.

A few hints concerning the compounds occurring, and the processes whereby they have been transformed in the laboratory must be sufficient in these elements.

211. Vastly predominant in plants are the so-called carbohydrates, composed of carbon, hydrogen, and oxygen, the last two in the proportion in which they form water (compare 158). Woody fibre, starch, gum, and the different kinds of sugar belong to this group of compounds.

212. In the sweet fruits of many plants the variety of sugar called grape sugar occurs; especially, also, in the ripe grape of the vine. When grape sugar solution is

mixed with a little yeast, fermentation sets in; the juice of the grape contains a natural ferment, which soon causes the fermentation of the must.

The process of fermentation is a peculiar disintegration of grape sugar into carbon dioxide and alcohol. The first* passes into the air; the latter can be separated by distillation. In the fermented must, called wine, the alcohol seems, however, not to be free, but combined in a very peculiar manner to the other manifold constituents.

213. Alcohol, obtained as just stated, constitutes the basis of organic chemistry. Innumerable compounds have been formed from it.

Slowly oxidized, alcohol becomes acetic acid; the impure and dilute article is the familiar vinegar.

Treated with chlorine, alcohol yields the highly important chloral. Treated with chlorine and potassa, the equally important chloroform results. A liquid containing alcohol, when heated with a little potassium hydrate and a minute quantity of iodine, gives in a like manner, iodoform, which upon cooling, separates in beautiful yellow hexagonal crystals (microscopic).

Alcohol, when mixed with sulphuric acid, yields, upon distillation, the well known ether (commonly called sulphuric ether, although it contains no sulphur nor sulphuric acid).

In this manner, thousands of peculiar compounds have already been prepared from alcohol.

Finally, alcohol results by fermentation from all substances which contain materials convertible into grape sugar; such materials we have in all the carbohydrates. Hence, alcohol is formed during the process of bread-baking, etc., etc.

214. Another class of organic compounds are the numerous acids found in animals (formic, lactic, etc.) and plants (oxalic, citric, malic, tannic, etc., etc). They com-

*How recognized? See 136.

bine with mineral bases precisely as the acids described in the preceding.

215. Corresponding to the bases or alkalies, we find especially in plants, but also in animals, complex bases* usually called alkaloids. Such are morphine, strychnine, nicotine, etc.

Thus we have strychnine sulphate, strychnine chromate, and many other salts. A great many of these alkaloid salts are important medicines, although most are poisonous. Strychnine is exceedingly poisonous.*

216. Complex compounds endowed with, or producing, splendid colors are also frequent; we may here refer to litmus and cochineal, used above (129, 149). Of late, many of the most brilliant colors have been prepared in the laboratory, especially the so-called aniline colors, from distillation products of coal tar.

As an example of beautiful organic colors, the student may perform Pettenkofer's test for the acids of the bile. To a drop of alcoholic solution of bile add a very little of sugar solution and a drop of dilute sulphuric acid; upon gently heating this mixture on the water bath, a beautiful purple color will develop.

217. The albuminous substances constitute a group of serial compounds most characteristic of the animal body. The white of egg contains a considerable portion of very pure albumin; in blood we find fibrine, and in milk we have casein. These albuminous bodies are essential to the formation of animal tissue, and after use as such, leave the body as urea.

* Strychnine and its compounds, when nearly pure, may be recognized by the following test: The white substance is moistened with the least possible amount of pure sulphuric acid, and a minute crystal of potassium bichromate added; a beautiful bluish purple will develop, which soon changes to purple, then to reddish orange and fades.

The student should, on a watch-glass, receive only one drop of the dilute strychnine solution, and test the white residue which remains after spontaneous evaporation.

The albuminous bodies consist of carbon, hydrogen, nitrogen, and oxygen, with some sulphur. The latter is indicated by the odor of fresh boiled eggs (compare 170).

By elementary analysis (158), the composition of these compounds has been found to be, for each one part of hydrogen :

Albuminous bodies :	H=1,	C=8,	O=3,	N=2.
Urea :	1	3	4	7

So that urea contains comparatively much more of nitrogen than the albuminous bodies.

218. These few examples must here suffice to indicate that the portion of chemistry here considered constitutes but the *E l e m e n t s* of *C h e m i s t r y*. The body of plants and animals furnishes abundant and much used material for chemical research ; the branches of the science termed *A n i m a l C h e m i s t r y*, *P h y s i o l o g i c a l C h e m i s t r y*, *A g r i c u l t u r a l C h e m i s t r y*, etc., treat especially of these subjects. Also, the very process of the material life on the globe is successfully being studied ; the relation of food to force and heat,—even the gaseous products of respiration and perspiration,—is being accurately investigated. Many important results have already been obtained by these researches. A few of these results will find a place in the third volume of these elements of physical science, in “*Cosmos* ;” but the details must of course be sought in special treatises.

219. A careful chemical investigation of the substances which constitute the solid crust of the earth has led to the science of *c h e m i c a l m i n e r a l o g y* and *p e t r o g r a p h y*.

The first elements of mineralogy will be found in the next chapter, while the elements of petrography will be set forth in the third volume of this course.

220. Special and full information on the various chemical manufacturing processes — some of which have been simply mentioned in this volume — must also be sought

for in special treatises on technical chemistry and metallurgy.

Similarly we must refer to analytical chemistry for the methods of determining the composition of any given substance; to systematic chemistry for a concise and classified description of the multitude of chemical compounds; to theoretical chemistry for the laws and principles which thus far have been firmly established as governing the processes of chemistry, and determining the specific properties of chemical compounds.

In the second year's course, embracing the Principles of Physical Science, we shall, in regard to chemistry (Vol. 2), mainly give theoretical and systematical chemistry. All the other numerous subdivisions of the vast field of chemical science must be left as special studies, to be taken up after the principles shall have been mastered.

CHAPTER VII.

ELEMENTS OF MINERALOGY.

I. Classification and Determination.

221. All but the serial compounds are prepared from the comparatively few chemical compounds which occur native, *i. e.*, in the solid crust of the earth, and are called minerals. The minerals necessarily form the basis of the great chemical arts, such as the smelting of the metals from the ores, the making of glass and pottery. The minerals also possess a high purely scientific importance, because nearly all are found in crystallized specimens, which exhibit at once the physical, morphological, and chemical properties of the chemical compound in a beautiful manner. El. Phys., 214.

For these reasons, we select the minerals or native compounds as the most useful material, both practically and scientifically, to study a large class of chemical compounds, and to learn to distinguish the individual compounds one from the other. Since water and air have penetrated much farther into the earth than miner or rock drill have ever reached, the minerals are almost completely restricted to those compounds which are insoluble in water, and not readily oxidized. Only where a large portion of the sea was cut off and dried up, we find deposits of soluble salts in the earth.

222. The teacher should thoroughly exemplify the terms and descriptions given in this section, by the exhibition before the class of about a dozen good (if possible, crystallized) large specimens, representing different groups of minerals (oxides, sulphides, etc). Thereby the students will be enabled to determine minerals

given to them in the laboratory practice following. Our mode of determination (see 230) compels the students to carefully study the description of all minerals repeatedly and in the most different order, so that they must become familiar with a great many. Consequently, the examination at the close of the term, while it should be most searching on species actually determined, may also extend to other minerals in general, and finally embrace the rapid and certain determination of some species not before examined by the student.*

223. A mineral is a native chemical compound (221). Each mineral species, therefore, is homogeneous (96), and contains its constituent elements in fixed proportions (97), so that its composition can be represented by means of a chemical formula (184).

224. We shall learn that each such compound has also quite definite physical and morphological properties (El. Phys., 214); so much so, that a careful observation of these physical and morphological properties (in most cases) leads with certainty to the chemical composition, while inversely, in theoretical chemistry, these properties are deduced from the chemical constitution.

Accordingly, we give in the next section a concise synopsis of the physical and morphological properties of the principal minerals, so that the student can learn the composition of each mineral, as indicated by its chemical formula. The concise synopsis of properties of a mineral is called the characteristic of that mineral.

225. Some minerals are actually almost chemically pure, and as free from any accidental ingredients as if they had been prepared with great care by an able chemist. But usually, more or less of matter not essential to the mineral has got into the same while growing in the

* Localities are not given, because the naming of a few places is absurd and leads to gross errors. The teacher, in excursions, etc., may exhibit the actual occurrence of minerals, and refer to certain well characterized mineral regions in our land. More about this in "Cosmos."

midst of the diverse materials amongst which we find the mineral. Such matters are termed impurities. They are often readily recognized in minerals of vitreous luster, having changed the color of the same. Thus, rock salt, when chemically pure, is white, and has vitreous luster; but a very little of organic matter tinges it green, blue, red, yellowish, etc.

But if the luster is metallic, a slight amount of impurity is not so readily detected. This gives rise to the following highly important practical rule:

The color of a mineral having metallic luster is constant, *i. e.*, characteristic; but the color of a mineral not having metallic luster is variable, *i. e.*, not characteristic.

Examples—Metallic: Pyrite, Galenite, Gold. Non-metallic: Quartz, Calcite, Fluorite.

226. All minerals having essentially the same composition, differing only by what may be termed impurities, belong to the same species of mineral. If their differences are sufficiently plain, they may individually be distinguished as varieties. See description of quartz (61) next section.

Such variation also extends, in a small degree, to specific gravity and hardness. In a few cases, the crystal form, and consequently the cleavage varies also; but although the last named modifications thus produced gives rise to varieties only, we shall, in the next section, follow the prevailing custom, and describe these morphological varieties as distinct species. Compare calcite 181.1 with Aragonite, 181.15; Pyroxene 203.3 with Amphibole 203.4; also, Rutile 61.4 with Brookite 61.5 and Octahedrite, 61.6. Such minerals are properly merely morphological varieties of the species represented by the chemical formula. If there are two such varieties, the compound is said to be dimorphous (181 and 203); if

there are three, the compound is trimorphous, as TiO_2 in 61.

227. Several species, the chemical formula of which differs only in the electropositive element, constitute a genus of mineral species, especially if the electropositives belong to nearly allied genera of elements. Compare 111, and the formula at the head of the first genera in the next section. Each mineral will be represented by two figures, the first indicating the genus, the second, the species. If varieties exist, they are denoted by a letter. Thus: 15, 2, c is cadmiferous sphalerite. See next section.

According to the electronegative, we group genera into orders and classes, as explained 123, and exemplified in the next section.

227. The members of a class of minerals may be distinguished by chemical means. Thus, the sulphides emit the odor of burning sulphur when heated on charcoal before the blow-pipe. Also, orders are chemically characterized. Thus nitrates deflagrate (95, note), silicates cause the soda-bead to effervesce (why, see 190), carbonates effervesce with acids (186).

Upon the application of such facts depends the determination of minerals by chemical means, an art which can only properly be acquired in a special course in determinative mineralogy.

228. The entire system of minerals is represented graphically on plate III. in a new manner, embracing the three most important properties, namely, hardness, H as ordinates; specific gravity, G as abscissae; and chemical composition, by the curve joining the species of the same genus.

In reality, a species on this chart occupies a certain area, because both H and G vary slightly (see the characteristics in next section). The dot representing the species on our chart is determined by the mean

values of H and G as given by the upper figure to the right of the main figure in the characteristic; the variation or range is given to the right, and below, at the same place. For hardness, the small figures indicate fourths; for gravity, they are tenths. Finally, H and G are always given in the second line, H preceding G. Thus, in genus 101, species 2 (see next section), we find H expressed by $3\frac{1}{4}$ and G by $3\frac{9}{10}$; that is, a mean hardness $3\frac{1}{4}$ with range $\frac{1}{4}$, so that H varies from 3 to $3\frac{1}{2}$; also, $G = 3.9$ mean, range 0.1, or varying from 3.8 to 4.0. This species 101.₂ (Celestite), is therefore represented on the chart by a point, the abscissa of which is $G = 3.9$, while its ordinate is $H = 3\frac{3}{4}$ (Compare *El. Phys.*, 74).

On this chart, the sulphides (to the right) and the silicates (to the left) are represented by full down lines; the carbonates by a waving line; all other genera by dotted lines. Anhydrous species are represented by dots, hydrated by minute circles, for the oxygen compounds. Chlorides and Fluorides by a dot with circle, Elements by a star.

229. The student can readily determine the hardness and specific gravity of a given mineral with an accuracy of one-half of a unit (*El. Phys.*, 150 and 123). He then finds the point on the chart represented by the mean value of H and G determined by him. The dot representing the mineral must then be found on the chart inside a square extending one-half unit (1 cm. on the chart) each way from the above point. The student enters in his Journal all species of the chart occurring inside this square (by the number of genus and species); by careful comparison with the description or characteristic of each of these minerals given in the next section, he finds which properties in the descriptions conflict with those observed; all such conflicts he enters in his Journal. The species not conflicting is the one which he has in hand. In this manner our chart is not only a con-

cise representation of the system of minerals, but also a most important guide in the determination of minerals.

230. The student having received a mineral for determination, carefully ascertains the optical, morphological, and molar properties of the same, and H* and G† (compare El. Phys. 216), entering a concise statement of his results in his Journal (for abbreviations, see 231). In this work he should use the material (mineral) furnished, precisely as directed. He should not try hardness of crystals, because that would injure the faces, nor try hardness on the larger, uncrystallized piece, given for the observation of luster, color, and cleavage faces. Nor should he break off fragments from either of the above to observe streak or cleavage, but he must use one of the small fragments expressly given for this purpose, which fragments must also be used for the determination of hardness, unless an extra piece is given expressly for this purpose. Finally, the minute fragments resulting from experiments on cleavage and streak must be put into the vial for that purpose.‡ The teacher must enforce these rules, for

*The hardness should be determined according to Mohs' scale (El. Phys., 150). 1, Talc. 2, Gypsum. 3, Calcite. 4, Fluorite. 5, Apatite. 6, Feldspar. 7, Quartz. 8, Topaz. 9, Corundum. 10, Diamond.

A crystal fragment of 2, 3, 4, 6, 7, is quite sufficient to serve as scale for student's work.

†It is advisable to use a balance weighing to the centigram; then

$$G = \frac{w}{w - w'}$$

Where w = weight in air, w' = weight in water (El. Phys., 123).

‡The teacher will see, from the above, what material is required. For any one species the material is best kept in a small paper box, which is handed to the student for use, with card label giving any special directions deemed necessary in regard to the material.

In each such tray is another card, containing the number of the mineral (genus and species; also, letter indicating variety) in accordance with the description given in the next section. This card the teacher does not show to the student, but puts it aside; he gives the student merely the current number in the teacher's private note-book, where he enters the name of student receiving the mineral, also genus, species, variety of mineral given. The student's reported result is also entered, so as to determine the value of the student's work. This note-book thus reads, for example:

315. Mr. Johnson	.	.	181, 1, g	.	181, 1, g
316. Miss Davies	.	.	203, 3, c	.	203, 3, f
317. Mr. Evans	.	.	230, 6	.	230, 6

otherwise no school can afford to give its pupils the material for this work free; hence, infringements of these rules must be followed by a fine sufficient to replace the injured specimen. Since the teacher has a record of the students who have used the specimen, this rule can be enforced.

In case but a single crystal is accessible, the teacher may state on a card those properties which to determine would injure the specimen; hence especially, H, cleavage and streak. Most specimens will, however, without actual trial, exhibit both the directions and degree of cleavage; smoothness of plane faces in fracture indicate rather perfect cleavage, while pearly luster indicates a highly perfect cleavage. At other times, the cleavage is also sufficiently manifest from cracks in the specimen. The card accompanying the specimen will give directions in this respect. For further details, see the example in 232.

231. Abbreviations. For H and G already explained in 228.

Angles are given in degrees and tenths thereof; thus, 0.1 is 6 minutes, and $121.6 = 121^{\circ}36'$ inside of $3'$ either side. This is more than accurate enough for these Elements.

Cleavage, Clv (El. Phys., 197, 198).		Degrees:	
em	eminent (highly perfect).	impft	imperfect.
pft	perfect.	diff	difficult.
dst	distinct.	tr	traces.

Luster, L (El. Phys., 208, 209):	
vit	vitreous
ad	adamantine*
m	metallic.
sm	sub-metallic.
d	dull, earthy.
prl	pearly.
slk	silky.
res	resinous.
gr	greasy.
wx	waxy.

* Like a diamond.

Diaphaneity or Opacity (El. Phys., 205, 206):

trsp	transparent.	strp	semi-transparent.
trl	translucent.	strl	trl on edges.
op	opaque.		

We give luster first, and often omit diaphaneity, if sufficiently determined by the luster; see El. Phys., 209.

Color, col., and Streak, str., the names of colors (El. Phys., 210):

bl	blue.	bn	brown.	bk	black
gr	green.	gy	gray.	etc	and other colors.
dk	dark.	dp	deep.	:	-ish.
or	orange.	p	purple.	r	red.
w	white.	y	yellow.	var	various.
clrl	colorless	pl	pale.	lt	light.

For example, gr:y = greenish yellow. Also, bn, etc. = brown, and other colors; implying, however, that brown dominates.

Form (El. Phys., 199; also, subsequent 233) and Structure:

a	amorphous.	tr	triclinic.
pr	prism.	m	monoclinic.
pyr	pyramid.	r	rhombic.
dm	dome.		
b	base.	q	quadratic.
o	octahedron.	h	hexagonal.
d	dodecahedron.	R	rhombohedral.
h	hexahedron.	t	tesseral.
R	rhombohedron.		

Structure and Aggregation:

cpt	compact.	fol	foliaceous
cryst	crystalline.	gran	granular.
mass	massive.	fib	fibrous.
rad	radiated.		
ren	reniform.		
stal	stalactite.		
stell	stellate.		

We are fully aware of the fact that this chapter is no interesting reading, but if the student carefully studies this chapter and works according to the directions here given, we know that he will be deeply interested. See 222.

232. The following may serve as an example, carried out according to the directions in 230. The student should, however, constantly bear in mind all that has been said in this section, in order to arrive at correct results:

No. 372. Mineral.

Description: Vit. strl. w. H $6\frac{3}{4}$ G 3.4 Form — no crystal given. Clv. 1 em; 2, forming pr. 130, pft, in same zone. Angle em: pft 115° .

230.4 Axinite — 3^3 clv. 1 dst.

240.2 Prehnite — 2_1^9 clv. 1 dst.

221.3 Fibrolite — — — clv. 1 pft.

221.1 Cyanite 5 to 7 3_1^6 clv. MT 106.3.

205.2 Epidote — gr. clv. M pft, T less 10, MT 115.4.

205.1 Zoisite — 3_1^3 clv. 1 pft, striat. longit.

81.4 Diaspor — — — —

207.2 Vesuvianite clv. 2 dst. 80° .

207.1 Garnet $7_3 3_6$ cryst. clv. dodec.

Hence, the given mineral is Diaspor, 81.4.

In a great majority of cases, the determination will be easier than the one here selected.

233. A single crystal, if only one of its extremities is sufficiently well developed, is quite sufficient to determine the mineral. As stated in 230, the hardness, cleavage, and streak should not be actually determined on the crystal, but be stated to the student by the teacher.* Cleavage and streak may, in most cases, be omitted entirely, if the form is carefully investigated according to the following directions (Compare, also, El. Phys., 174, 175):

* In actual practice, when a new specimen has been found, H, Clv. Str, are determined carefully on those portions of the crystal which are either broken, or not developed.

See whether the crystal has a plane of symmetry, or not. If it has no plane of symmetry, it is TRICLINIC; it is then one of the following minerals: $130_{,5}$; $161_{,11}$; $211_{,2,3}$; 221_1 ; $230_{,4}$; $275_{,11}$. Compare figures 48, 49, 50 and the description of these species.

If the crystal has a plane of symmetry, place this plane vertical fronting you; then the crystal has symmetry of right and left. Now ascertain whether it has symmetry of back—front or above—below. If it has no symmetry but right and left, the crystal is monoclinic, and must be one of the following minerals: 22^1_1 ; 91^1_1 ; $111_{,11}$; $130_{,4}$; 141^1_1 ; 171^1_1 ; $181_{,20}$; $200_{,11,2,3}$; $203_{,2,3,4}$; $205_{,2,3}$; 211_1 ; $230_{,2}$; $240_{,9,13}$. Compare, also, Figs. 40 to 47.

If, however the crystal has an additional plane of symmetry (above—below or front—back), then it is either rhombic, like Figs. 18 to 28, or it has rotary symmetry besides. A crystal has rotary symmetry if its faces appear precisely the same (also, in inclinations) after a rotation of 60° , 90° , or 120° around the vertical axis of symmetry. If, after a rotation of 120° , the crystal in three positions appears the same, the crystal is rhombohedral (R), like figures 30 to 38; in these forms each face occurs exactly three times about the vertical in the same relative position. If the angle be 60° , then each face occurs six times, as in Fig. 29, and the crystal is hexagonal (h). If the angle of rotation is 90° , then each face occurs four times, and the crystal is quadratic (q), as in figures 13 to 17.

But if a crystal finally have both the rotary symmetry of 90 degrees around one axis, and of 120 degrees around another, it is both q and R, or tesseral (t), as in figures 1 to 12. Instead of this statement, we may also say that tesseral crystals have three axes of quadratic symmetry.

The following are the minerals having these degrees of symmetry :

R are: $4_{,1,2,3}$; $5_{,1}$; $15_{,10}$; $45_{,1,2}$; $61_{,1}$; $64_{,1,2}$; $80_{,1}$; $130_{,6}$; $151_{,2}$; $181_{,1,2,3,4,7,8}$; $201_{,1,3,4}$; $214_{,2}$; $230_{,3}$; $240_{,8,15}$.

h are: $12_{,1}$; $31_{,10}$; $67_{,2}$; $71_{,10}$; $80_{,2}$; $135_{,1,2}$; $220_{,2}$; $230_{,1}$; $240_{,17}$.

q are: $31_{,1}$; $61_{,3,4,6,7}$; $83_{,1,2}$; $88_{,2,3}$; $90_{,1}$; $207_{,2}$; $220_{,2}$; $240_{,5}$.

t are: $1_{,1,2,3}$; $2_{,1}$; $3_{,1,2,4}$; $11_{,1}$; $15_{,1,2}$; $18_{,2,3}$; $41_{,1,2}$; $67_{,1}$; $71_{,1}$; $81_{,2,3}$; $82_{,1}$; $84_{,1}$; $130_{,10}$; $165_{,1,2}$; $207_{,1}$; $220_{,1,4}$; $240_{,4}$; $271_{,1}$; $281_{,1,2}$.

r are: $5_{,2}$; $11_{,2,11,21}$; $18_{,1}$; $21_{,1,2,3}$; $45_{,3}$; $61_{,15}$; $81_{,1,4}$; $83_{,3}$; $84_{,2}$; $88_{,1}$; $101_{,1,2,3,4}$; $130_{,1,2,3}$; $150_{,1,3,4}$; $151_{,1}$; $181_{,15,16,17,18}$; $201_{,2}$; $203_{,1}$; $205_{,1}$; $214_{,1,3,4}$; $221_{,2,3}$; $230_{,5,6}$; $240_{,1,2,3,4,6,7,12,14,16,20}$; $290_{,2}$.

After the degree of symmetry has been determined, the specific gravity and hardness alone will suffice to reduce the number of possible mineral species which the crystal may be from the above given lists to very few. A closer inspection will then decide which of these few the crystal is.

To decide on the degree of symmetry, often more careful measurements are required than the student can make. Thus, chalcopyrite (see 31_1) was considered tesseral, even by Haüy, until Haidinger's careful measurements proved it to have but one axis of quadratic symmetry (Fig. 16.) In such doubtful cases, the student must of course pass all species above given under the possible degrees of symmetry.

234. The student should, in this connection, carefully review *El. Phys.*, 190, 191, 194, 195, and 199. He will then remember that the truncature of the corners of the octahedron (Fig. 1) give the hexahedron — cube — (Fig. 3); also, that the truncature of the edges of the octahedron gives the dodecahedron (Fig. 2). He will then also readily see that the truncature of the edges of the hexahedron (Fig. 3) likewise leads to the dodecahedron, while the truncature of the corners of the hexahedron leads back to

the octahedron. Finally, the truncature of the four-sided corners of quadrative symmetry in the dodecahedron gives the hexahedron, while truncature of the three-sided corners of rhombohedral symmetry leads from the dodecahedron to the octahedron. Compare the figures 1, 2, and 3. The angles between these faces remain, also, constantly the same; namely (see *El. Phys.*, 190):

hh' 90. ₀	oo' 109. ₅	dd' 120. ₀
ho 125. ₃	hd 135. ₀	od 144. ₇

These three forms, therefore, occur together (see Fig. 8), in combinations. Other tesseral forms, resulting in a similar way from either of these three, are:

The leucitoid, or trapezohedron, Fig. 5; the galenoid, Fig. 4; the fluoroid, Fig. 6; the adamantoid, Fig. 7.

These forms are complete, and are termed holohedral; but if only the alternate faces in the octahedron (Fig. 1) are retained until they intersect, the tetrahedron (Fig. 11*) results. If corresponding part of Fig. 5 is developed, the cuproid (Fig. 12) results, while from Fig. 6 follows, in a slightly different manner, the pyritohedron, shown in Fig. 10, in combination with the hexahedron. See minerals: 165,₁; 41,_{1,2}; 11,₁.

Further particulars about crystal form must be sought in special works on Crystallography (See the author's *Principles of Pure Crystallography*). Enough will here have become evident to create the conviction in the mind of each student, that the forms of crystals are determined by mathematical and physical laws of the deepest interest and the highest importance to physical science.

* This shows the faces of the other tetrahedron, also.

SECTION II.

DESCRIPTIVE MINERALOGY.

Class I.—Native Elements.

Most are metals, possessing both metallic luster and malleability.

1. CUPROIDS, Kv . Important minerals.

1. Gold. Au. m. y.

$2_1^{317}_{20}tClv$. 0. mall. gran.

2. Silver. Ag. m. w.

$2_1^{310^3}tClv$. 0. mall.

3. Copper. Cu. m. r.

$2_1^{356}tClv$. 0. mall.

2. SIDEROIDS, Σd . Only in meteorites.

1. Iron. Fe. m. gy:w.

4^{27}_3tClv . 0. magnetic. Meteoric iron; usually containing considerable Ni, also, a little Co.

3. TITANOIDS, $T\tau$. Nearly infusible.

1. Platinum. Pt. m. gy:w.

$4_1^{117}_{15}tClv$. 0. gran.

2. Palladium. Pd. m. gy:w.

$4_1^{113}tClv$. 0. gran.

11. Graphite. C. sm-d. bk.

$1_3^{32}tClv$. 1pft.

10. Diamond. C. trsp-op. colrl. etc.

$10\ 3^5tClv$. 4, octah. pft. Hardest body; most costly gem, diamond of n carat, worth \$60.n². Above n=20, much more. Black diamond is cheaper; opaque.

4. PHOSPHOIDS, Φ . Bp. incr.

1. Bismuth. Bi. m. r:w.

$2\frac{1}{2}9^7R, 87, Clv.P.pft$; 6 forming 2 rhomboh. of 69.5 less so. Fig. 38; important ore.

2. Antimony. Sb. m. gy:w.

$3\frac{1}{2}6^7R, 87.6, Clv.P.em$. 3 forming 1 rhomboh. 117.1 dst. Fig. 38.

3. Arsenic. As. m. gy:w. tarnish.

$3^25^9R, 85.7$. Clv.P. impft (Fig. 38).

5. SULPHOIDS, θ .

1. Tellurium. Te. m. w (Fig. 38).

$2\frac{1}{2}6\frac{1}{2}R, 87.0, Clv.3, a pr.120, pft.P, impft$.

2. Sulphur. S. res. y.

$2_22^1r, pr.M101.8, Clv.2pr, impft$ (Fig. 27). Obtained in great quantities. Po.108.3—Pp.117.7.

Class II. Sulphides — Single and Double.

Bp. odor of burning S (231). G high, above 3, and H low, usually below 4, except for pyrites ($H=6$). Metallic luster; opaque and brittle, with few exceptions.

Double sulphides contain usually As or Sb, indicated Bp. by garlic odor or white fumes.

A. SINGLE SULPHIDES.**11. Pyrites, $\Sigma\delta R_2$.**

1. Pyrite. FeS_2^* . m. pale, brass, y.Str.gr:bk, br:bk.

$6\frac{1}{2}5_tClv. 0$. Forms, h, o, d, and pyritohedron, f, Fig. 10; h striated parallel to edges. Beautiful forms,—the gem among sulphides. $h'f'153.4, f''f'''126.9$; a, common; b, contains gold in most gold regions (Auriferous P.), but not in other localities. Exceeding abundant. Syn: fool's gold, iron pyrites.

* Dimorphous, two distinct forms; distinguish by form, color, G.

2. Marcasite, Fe S_2^* . m. bronze-y; gr. Str.gy:bk.

$6\frac{1}{4}\frac{8}{3}\text{r}$, pr.M106.1 clv.2 pr.M prft (Fig. 23). Often rad. ll.80_g.

11. Arsenopyrite, FeSAs . m. w. Str. gy:bk.

$5\frac{3}{6}\frac{3}{3}\text{r}$, pr.M111.9 clv.2 pr.M dst. Mispickel.ll,99.9.

21. Leucopyrite, FeAs_2 . m. w. Str. gy:bk.

$5\frac{1}{7}\frac{8}{3}\text{r}$, like 11. white pyrites. This genus contains also species containing Ni.,Co.

12. SUBPYRITES, $\Sigma\partial R$.

1. Niccolite, Ni As . m. copper-r. Str. br. bk.

$5\frac{1}{7}\frac{5}{3}\text{h}$. tarnish bk. Principal nickel ore; vulg. copper nickel.

15. GALENITES, $K\partial S$.

1. Galenite, $\dagger \text{Pb}$. m. Col. Str. lead-gy.

$2\frac{2}{7}\frac{7}{3}\text{t}$ clv.3, cube, em. (Fig 8.) a, Principal lead ore; b, often contains a little silver, which is obtained by cupellation (see 168). Argentiferous galena.

2. Sphalerite, Zn . res-ad. trsp-trsl. br,bk, etc. Str.w.etc.

$3\frac{3}{4}\frac{4}{2}\text{t}$ clv.6, dodec. em. Var. a, pure, w. cleiophane; b, br, bk, contains iron, marmatite or blackjack. c, contains Cd, is radiated, ad. luster, Przibramite.

10. Cinnabar, Hg . ad-dull. r. Str. scarlet.

$2\frac{1}{9}\frac{0}{R}$, 92.6 clv. 2, a pr. 120, pft. Mercury ore.

18. CHALCOCITES, $K\upsilon_2S$. Important ores.

1. Chalcocite, Cu . m.col. Str.bk:gy. tarnish.gr.

$2\frac{3}{5}\frac{7}{3}\text{r}$, pr.M119.6 clv.₂, M impft (Fig. 21). Copper-glance, vitreous copper.

2. Bornite, Cu . m. r-br. Str.gy:bk.

$3\ 4\frac{5}{1}\text{t}$ clv.4, octah.tr. Contains much Fe. Horse-flesh ore, from colors of tarnish.

\dagger Hereafter, only the electro-positive in the species is given, the one represented by the general symbol in the genus.

3. Argentite, Ag. m. bk:gy. Str.m.
 $2\frac{1}{2}7\frac{3}{4}$ t clv. 6, dodec. tr. Silver-glance, vitreous silver.

21. STIBNITES, Φ_2S_3 .

1. Bismuthinite, Bi. m. gy. tarnish.
 $2\ 6^r$, pr.91.5 clv.2pft, 1 impft, at right-angles to each other.
 2. Stibnite, Sb. m. gy.
 $2\ 4^r$, pr.90.9 clv.1cm. Antimony glance; principal Sb ore.
 3. Orpiment, As. prl, res. strsp.-strsl. y.
 $1\frac{3}{4}3^r$, pr.100.7 clv.1cm. Compare 22, 1.

22.

1. Realgar, As S, res. Col, r, Str, or.
 $1\frac{3}{4}3^m$ clv.2pft.

30.

1. Molybdenite, MoS_2 . m. gy. Str.gr:gy.
 $1\frac{1}{4}4\frac{6}{7}$? clv.1cm.

B. DOUBLE SULPHIDES, OR SULPHOSALTS.

31.

1. Chalcopyrite. $Fe_2S_4Cu_3$. m. deep brass-y. str.gr:bk.
 $3\frac{3}{4}4\frac{1}{2}q$, nearly t. clv. indst. Fig. 16. oo'109.9.
 oo''' 108.7; in tesseral (Figs. 11 and 1).
 oo'=oo''=109.5. Copper pyrites, good copper ore.

31.

10. Pyrrhotite, $FeS^?$ m. bronze y-r. str.gy:bk.
 $4\frac{3}{4}4^h$ Fig. 29. clv.P.pft. 3 pr. M of 120 less so.
 Magnetic; hence name: magnetic pyrites.

35.

1. Berthierite, FeS_4Sb_2 . m. gy-bn.
 $2\frac{3}{4}4\frac{2}{3}$? clv. 1 indst.

41. TETRAHEDRITES, $R_4S_7\Phi_2$. Fahlerze.

1. Tetrahedrite, Cu-Sb. m. gy-bk to r.
 $3\frac{3}{4}4^st$, tetrahedral, Fig. 12. Half of trapezohedron, Fig. 5, with half of octahedron, Fig. 1.
 2. Tennantite, Cu-As. m. bk: str. r:gy.
 $3\frac{3}{4}4^st$ clv. 6. dodecah. impft. These often contain Ag in place of Cu.

45. PYRRARGYRITES, $RS_3\phi$. Rothgueltigerze.

1. *Pyrrargyrite*, Ag-Sb. m-ad. bk-r. Str. r. $2\frac{1}{2}5^8R$ 108.7 the clv. 3, R impft. Ruby silver ore. Dark red silver ore. Figs. 31, 32.
2. *Proustite*, Ag-As. ad. strsl. Col. Str. cochineal-r. $2\frac{1}{2}5^5R$, 107.8. Light-red silver ore.
3. *Bournonite*, Pb and Cu, S. m. gy-bk. $2\frac{3}{2}5^8r$, pr. 93.7, clv. 3, impft. at 90° .

Class III. Oxides—Single and Double.

Most vitreous luster; in general, H greater and G less, than for sulphides. No single and simple chemical test distinguishes these, the most numerous of all minerals.*

The double oxides, or salts, are also easily distinguished by order reactions; for example, the carbonates (227).

Hydrated minerals are also easily distinguished from anhydrous, by the former yielding water when heated in a glass tube (92).

A. SINGLE OXIDES.**61. QUARTZITES, $T\tau O_2$.**

1. *Quartz*, Si. v-res, d. colrl, etc. Str. w. etc. $7_1 2\frac{7}{2}R$, 94.25. clv. none.

Fig. 30. $RR=rr=94.25$. Rr 133.7 $RM=Mr=141.8$ M striated horizontally. R and r often nearly equal in size, so that the crystals appear hexagonal. Varieties:

A. Crystallized. a, Rock Crystal, trsp. colrl; b, Amethyst, trsp. violet; c, Rose Quartz, rose col.; d, Smoky Quartz, y:br, often trsp; e, common cryst. quartz. trsl. col. various.

B. Massive crystalline. f, common quartz rock, g, milky quartz, h, ferruginous quartz (red).

* Test is not necessary either, for if not S-ides, nor elements, it follows that a given mineral belongs to the oxides. The fourth class contains but few.

C. Not crystalline; res luster, strl-trsp; i, chalcedony, gy, bn, etc.; k, carnelian, r.; l, chrysoprase, apple-gr; m, prase, dull leek-gr; n, plasma, bright gr; o, heliotrope, plasma with small spots of red jasper.

p, Agate, various (i to o) usually banded so as to form a variegated stone. q, if bands even planes, especially great contrast in colors (bk-w, bn-w), onyx.

r, Flint, only strl, gy, bl: Splits off in sharp edges; tough.

s, Hornstone; more brittle, less trsl than flint.

D. Opaque, dull; t, jasper, colors various, often variegated (Ribbon J); colors mostly r and y from iron. u, Basanite (Lydian stone, touchstone), black, flinty jasper.; v, silicious sinter, deposited from silic. water; w, Quartz-sandstone, grains of quartz; x, sand, loose, irregular grains of quartz.

2. Opal; hydrated SiO_2 . vit, res, prl. trsp. op. col. various, play.

$6_2 2\frac{1}{2}$ amorphous. Varieties:

a, Precious opal, brilliant, delicate play of colors; b, fire opal, red tints predominate in colors; c, common opal, w, y, bl, r.; d, semi-opal; e, wood opal, y: w; structure of wood; f, hydrophane, trsp in water; g, hyalite, colrl. trsp. globular crusts; h, silicious sinter; i, jasp-opal; k, tripolite.

3. Cassiterite, Sn. ad. trsp-op. bn-bk. str. gy: bn:

$6\frac{3}{4} 6\frac{1}{4}$ q. clv. pr. ? Fig. 13 (isom 61,7) Mo 133.6 Mh 135. Var. a, ordinary, tin-stone — mass; b, wood tin, masses of concentric layers, rad.; c, stream tin, gran. loose like sand and gravel. The only tin ore.

4. Rutile, TiO_2 m-ad. strl-op. r:bn. Str. bn, pale.
 $61\frac{1}{2}^\circ$ q, Fig. 13, isom. 61.7 clv. 2 (M) dist. 2 (h)
 less so. oo' 123.1, Mo 132.3, Mh=135.
5. Brookite, TiO_2 . m-ad. str. bn. Str. gy:, y:.
 $53\frac{1}{2}^\circ$ r, clv. 1.
6. Octahedrite, TiO_2 . m-ad. trl. br:, bl. str.
 clrl.
 $43\frac{3}{4}^\circ$ q, Fig. 14, clv. 5, pft. (P and o) oo'97.9,
 tP 119.4, oP 111.7. Anatase. Hence, TiO_2
 is trimorphous; distinguish by form, cleav-
 age, G.
7. Zircon, Si and Zr. ad. trsp-op. clrl y: br,
 etc. str. clrl.
 $72\frac{1}{4}^\circ$ q. Fig. 13. clv. 2 (M) impft. 4 (o) less dst.
 oo' 123.3 Mo 132.2. Very rich in forms,
 gems clrl y, jargons; br, or, r: hyacinths.
15. Pyrolusite,* Mn. m. op. bk,gy. str. bk.
 $21\frac{1}{4}^\circ$ r, pr.93.7. cl. 4, in 2 zones. Principal
 source of Mn; black oxide of Mn. Impure:
 Wad. See 83, 10.

64. HEMATITES, $\Sigma_2\text{O}_3$.

1. Corundum, Al vit, prl. trsp-trl. Str. clrl.
 Col. var.
 9 40° R, 86.1 (Fig. 38), clv. P, pft†; also R.
 Trsp. crystals, gems; a, sapphire bl.; b, ori-
 ental ruby r; c, oriental amethyst o; d, oriental
 topaz, y; e, oriental emerald, gr.
 f, not trsp.; massive or cryst, corundum, gy,
 bl:, bn: etc.
 g, Massive, op. bk, gy:bk, containing magnet-
 ite and hematite — emery.

* Given by way of appendix to this genus, to which it does not properly belong.

† But not continuous.

2. Hematite, Fe. m. d. bk, gy. Str. cherry-r.
 6_2 4_1^9 R, 86.1. clv. 1. P and 3, R, indst. nn 143.1,
 ss 122.5. Beautiful crystals: Elba Roses, Fig.
 34. Var: a, specular iron, m; if fol. micaceous;
 b, compact col. or fibr.—red hematite; c, red
 ochrous H.—earthy, clayey (reddle); d, clay
 iron-stone, impure, hard; at times, oolitic. Im-
 portant iron ores.

67. PERICLASITES, KdO .

1. Periclase, Mg. vit. trsp-trsl. gy-gr.
 6 3^7 t clv. 3, cube, pft.
 2. Zincite, Zn. ad. deep r. Str. or.
 4_1^1 5_2^6 h clv. 1, b. em. —. Red zinc ore;
 important ore.

71. CUPRITES, Kv_2O .

1. Cuprite, Cu. ad-sm. r. str. bn:r.
 3_1^3 6_2^9 t clv. 4, octah. Ordinary: a, red copper
 ore, cryst. or mass; b, tile ore, impure;
 from iron oxide.
 10. Ice, H. vit. trsp. clrl. str. w.
 2 0.92 h, Fig. 39, a snow star.

80. HYDRATED OXIDES.

1. Brucite, MgO_2H_2 . prl, slk. trsl. w:etc. str, gy.
 $2^3 2_1^3$ —R 82.4 Fig. 38. Clv. P, em. basal; var.
 a, common, fol.; b, nemalite, fibr.
 2. Gibbsite, $Al_2O_6H_3$. prl. vit. w:
 3_2^0 2_1^3 h, small hexag. cryst.; clv. 1, em.

B. METALLOSALTS.

81. ALUMINITES, RO_4Al_2 .

1. Chrysoberyl, Be. vit, trsp-trl. Col. var.
 Str. clrl.
 8^3 3_2^6 r, Clv. 3 dst (M M T), nearly hexag. pr.
 and perpendicular to P, base, impft. Fig. 20.
 MM 119.8, MT 120.1. var. a, ordinary, pale

gr. b, Alexandrite, emerald gr in reflected light, deep red by transmitted light; crystals most beautiful, often large, in groups, resembling snow-stars.

2. *Spinel*, Mg. vit. trsp-op. Str. w. Col. var. 8 3_1^3 t Clv. 4 (oct). a, red, ruby. b, dark gr, br, bk, etc. Pleonast. Finer, varieties, gems.
3. *Gahnite*, Zn. vit. grs. strsl-op. dk gr. Str. gy. 7_1^3 4_3^3 t, like 81.2. a, Automolite, pure Zn. b, Dysluite, contains Zn and Mn. c, Kreittonnite, Zn and Fe.
4. *Diaspor*, H_2 . vit, prl. trl-strl. w.; gy.; gr. 6_1^3 3_1^4 r Fig. 20. Clv. T em, pr. MM' less so; TMM' six-sided pr, MM' 129.8, TM 115.1.

82. CHROMITES, RO_4Cr_2 .

1. *Chromite*, Fe. sm. op. bk. str. bn. 5^2 4_1^5 t, mass, gran. Chromic iron; the principal source of Cr. Impurities: Mg - Al.

83. MANGANITES, RO_4Mn_2 .

1. *Hausmannite*, Mn. sm. op. bn:bk. Str. bn. 5_1^4 4^7 q. Clv. 1, basal, pft. See 82, 1.
2. *Braunite*, Mn. with Si. sm. bn:bk, str. bn:bk. 6_1^4 4_1^7 q, very nearly t.
3. *Manganite*, H_2 . sm. op-strl. gy-bk. str. r:bn, bk. 4 4_2^3 r, pr. 99.7 Clv. 2, the pr. pft; 1, cutting off the acute angle of pr, more so.
10. *Psilomelane*, 5_2^3 4_3^3 sm. bk,—amorphous. Impure, Wad. H $\frac{1}{2}$ to 6. G 3 to 4.3. See 82, 1.

84. MAGNETITES, RO_4Fe_2 .

1. *Magnetite*, Fe. m-sm. op. bk. str. bk. 6_2^0 5_2^3 t; o and d. Clv. 4, o. Always strongly magnetic; often magnetized (El. Phys., 303, 304, 323), when called lodestone. Magnetic iron ore; abundant, good. See 82, 1.

2. Goethite, H_2 . ad. strl. y; r; bk:bn. str. bn:y.
 $5\frac{1}{2}$ $4\frac{3}{2}$ r, pr. 94.9. Clv. 1, very pft.
10. Limonite, H_n . slk, sm, d. bn. str, y:bn.
 $5\frac{3}{2}$ $3\frac{8}{2}$ a. Iron ore, varieties: a, empct, sm, brown iron stone. b, Ochreous, more y, also earthy, clayey. c, Bog ore, porous. d, Brown clay ironstone, empct, often gran, grains small; e. Oolitic; large; f, Pisolitic. Brown hematite, ochre, etc.
- 88. WOLFRAMITES, RO_4Wo . Wolframates.**
1. Wolframite, Fe, Mn. sm. op. gy; bn:bk. Str. r:bn, bk.
 $5\frac{1}{2}$ $7\frac{3}{2}$ r pr. 101.1. Clv. 2, at 90° .
8. Scheelite, Ca. vit-ad. trsp-trl w: str. w.
 $4\frac{3}{2}$ $6\frac{0}{2}$ q. pyr. 100.1 Clv. 4, pyr. dist. Tungsten.
9. Stolzite, Pb. res-s:ad. strl. gr, gy, etc. Str. clrl.
 3^0 $8\frac{0}{2}$ q. pyr. 99.7. Clv. 1 impft; 4 more so.
- 90. 1. Wulfenite, PbO_4Mo . res-ad. strl-strsp. y, etc. Str. w.**
 3 $6\frac{5}{2}$ q, pyr. 99.7. Clv. 4, pyr. pft. Lead Molybdate.
- 91. 1. Crocoite, PbO_4Cr . ad-vit. trl. r. Str. or.**
 $2\frac{3}{2}$ $6\frac{0}{2}$ m. pr. 93.7. Clv. 2 pr. dist.
 C. SALTS (proper).
 a, Sulphates, anhydrous; 111, 130, hydrous.
- 101. BARITES, RO_4S .**
1. Anhydrite, Ca. prl. vitr. w, etc. Str. w.
 $3\frac{1}{2}$ $2\frac{0}{2}$ r, pr. 100.5. Clv. 3, pft. at 90° .
2. Celestite, Sr. vit-prl. trsp-strl. bl; w. Str.w.
 $3\frac{1}{2}$ $3\frac{1}{2}$ r Fig. 24, pr. M 104.0 Clv. P pft, pr. M dist. Usually columnar after Pq.
3. Barite, Ba. vit-res. trsp-op. w, etc. Str. w.
 $3\frac{2}{2}$ $4\frac{5}{2}$ r, pr. M, 101.7 Clv. P, pft; M, less so. Heavy spar, Fig. 24. Usually tabular after P. Pq 127.3. Pr 141.1

4. *Anglesite*, Pb. ad, res, vit. trsp-op. w, etc. Str. w.

3 $6\frac{3}{4}$ r, pr. M, 103.7 Clv. 1, Pand 2, pr. Lead vitriol. Fig. 24; often rather equally extended in the three dimensions.

111. *Gypsum*, $\text{CaO}_4\text{S}+2\text{H}_2\text{O}$. prl-d. trsp-op. w, etc. str.w.

$1\frac{1}{2}$ $2\frac{3}{4}$ m, Fig. 43, ff 111.4 ll 143.7 Clv. 1, P, em, fol.; 1, M, conchoidal; 1, T fibr, silky; both at right angles to P, and MT 113.1. Var.: a, Selenite, when cryst., trsp. b, Satin spar, fibr. slk; plumose g., rad. fibr. c, Massive g: alabaster, gran. w; rock-g, less pure.

130. VARIOUS HYDRATED SULPHATES.

1. *Kieserite*, Mg S-ate, 13% water. w.

2^2 2^5 r — slightly soluble.

2. *Epsomite*, Mg S-ate, 51% water. w.

2^1 1^7 r, nearly q. Clv. 1 pft. efflor. Epsom salt, El. Phys., 185. Sol.

3. *Goslarite*, Zn S-ate, 44% water. w.

$2\frac{1}{2}$ $2\frac{0}{1}$ r, nearly q. Clv. 1 pft. efflor. White vitriol, El. Phys., 184. Sol.

4. *Melanterite*, Fe S-ate, 45% water. pale gr.

2 1^8 m, nearly R. Clv. 3; P pft, M less so. Fig. 40. MM' 82.3; PM 80.6. Sol. Green vitriol. Efflor; turns y, ochery.

5. *Chalcanthite*, Cu S-ate, 36% water. bl.

2^2 2^2 tr. Clv. 0. Fig. 50. Sol. MT 123.1 PT 127.7 MP 109.3 Tn 148.8 Pn 120.8. Blue vitriol, copper vitriol. El. Phys., 177.

6. *Alunite*, Ka-Al S-ate, 13% water. w.

$3\frac{3}{4}$ $2\frac{1}{4}$ R, 89.1. Clv. P, pft. Fig. 38. Alumstone.

10. *Alums*, various. See El. Phys. 194, 195. t. sol.

b, *PHOSPHATES*, anhydrous; 141, 150, hydrous.

135. APATITES, $R\text{Cl}_2 + 3(R_3[\text{O}_4\text{P}]_2)$. Fig. 29.

1. Apatite, Ca. vit-res. trsp-op. gr, etc. str. w.
5 $3\frac{1}{2}$ h. Fig. 29. Clv. P, impft. pr. M more so.
Asparagus stone. Osteolite, phosphorite.
2. Pyromorphite, Pb. res. strsp-strl. gr, br,
etc. Str. w, y:
 $3\frac{3}{4}$ $6\frac{0}{3}$ h Clv. tr. Fig. 29. a, Green lead ore.
b, Brown lead ore.

- 141. 1. Vivianite, Fe P-ate , 29% water. w, bl: str. clrl, etc.**
 $1\frac{3}{4}$ $2\frac{6}{4}$ m, pr 111.2 Clv. 1, pft; 2, tr.

150. VARIOUS HYDRATED PHOSPHATES.

1. Struvite, Mg-H P-ate, 44% water. vit. trsl-op. y:
2 1^7 r, Clv. 1 pft. The same as microcosmic salt.
3. Olivenite, Cu P-ate, 3% water, much As. ad-vit. strl-op. gr:bn. Str. gr-bn.
3 $4\frac{3}{2}$ r pr 92.5 Clv. tr. Olive copper ore.
4. Wavellite, Al P-ate, 28% water. vit-prl. trsl. w, gr, y, bn. bk. Str. w.
 $3\frac{3}{2}$ 2^3 r pr 126.4 Clv. 2, pr. pft; 1. Usually rounded concrete, rad. fibr. structure.
6. Turquoise, Al P-ate, 20% water; with Cu. wax. strl-op. bl, bl:gr, gr. Str. w, gr:
6 2^7 a. renif.stalact. Calaité, Oriental T; finer var. as gems.

c. NITRATES.**151. NITRATITES, $K\alpha\text{O}_3\text{N}$. Deflagrate on Chic.**

1. Nitre, Ka. vit. strsp. w. Str. w.
2 1^9 r (Fig. 26). Clv. M, impft. MM' 119.4,
Mo. 120.3, DD' 109.8. Saltpeter (see El. Phys., 181); sol.
2. Nitratite, Na. vit. strsp. w. Str. w.
 $1\frac{3}{4}$ $2\frac{2}{4}$ R, 106.5 (Fig. 31). Clv. 3, R, pft. Chili saltpeter (El. Phys., 186); sol.

d. BORATES.

- 161.** 1. *Sassolite*, hydrogen borate. prl. w.
1 1⁵ tr. Clv. 1, em. sol.
- 165.** *BORACITES*, RO_4Bo , part of O replaced by Cl.
1. *Boracite*, Mg. vit-ad. trl. w,y,gr:
7 (massive 4.₂), 3₁⁰ t, tetrah. Clv. 4, oct. tr.
The massive variety yields water.
2. *Rhodizite*, Ca. vit-ad. trl. w.
8 3₁³ t, isom. 165.1.
- 171.** 1. *Borax*. $\text{Na}_2\text{O}_7\text{Bo}_4 + 10 \text{H}_2\text{O}$. vit-res. w.
2₁¹ M (Fig. 44). Clv. K, pft; T less so. TT
87.₀, oo' 122.6.

e. CARBONATES.

Effervesce with acids. 181 anhydrous. 200 hydrated.

- 181.** *CALCITES*, RO_3C . Dimorphous, esp. Ca. Species 1 to 8, isom. 151.2; species 15 to 18, isom. 151.1.
1. *Calcite*, Ca. vit-d. trsp-op. w, etc. Str. w,gy:
3₂ 2₁⁶ R, 105.1. Clv. 3 (R) em. Forms, very rich — dominant are:
1. Fundamental rhombohedron, R, fig. 31.
 2. Hexag. pr. M of 120.0, with rhombh. r of 135.0, fig. 32.
 3. Scalenohedron S, fig. 33, with R (Dog-tooth spar); angles SS' 144.4, SS'' 104.6, SS''' 133.0.
- Varieties exceedingly numerous:
- a. Crystallized; finest, trsp. Iceland spar; all clear cryst.: Double spar, showing double refract (El. Phys. 291).
 - b. Fibrous: Satin spar, silky. See 111.1.
 - c. Granular, cmpet:
 - d. Crystalline, Marble proper. e, w. saccharoidal limestone. f. Variegated, cryst. or cmpet: Marbles, numerous varieties.

-
- g. Compact limestone, gy, w, etc.
 - h. Lithographic stone, very fine grained.
 - i. Hydraulic limestone; impure, either cloy or Mg.
 - k. Shell marble, coralline marble, etc., from fossils.
 - l. Chalk, soft, friable, w. m. Rock-meal, rock-milk, exceedingly friable, w. n. Marl, very clayey.
 - o. Oolite, gran. concretions; p, if large, pisolite.
 - q. Stalactites (hanging), and, r, stalagmites (standing) cones, etc., in caves; often fine structure, caucentric layers, various colors.
 - s. Tufa, calcareous sinter, deposits from calcareous waters.
2. Dolomite, Ca, Mg. vit-prl. trsp-trl. w, etc. Str. w.
 $3^8 2^8$ R, 106.3, isom. 181.1. Clv. 3 (R), pft. Pearl spar, cryst. curved faced, prl. Brown spar, w, y:, turns bn after exposure to air, from Fe-ous C-ate. Gran., cmpct, rock.
 3. Magnesite, Mg. vitr. trsp-op. w, y:, bn.
 $4_2 3_2$ R, 107.5. Clv. 3 (R), pft. isom. 181.1. If feriferous, Breunerite.
 4. Smithsonite, Zn. vit-prl. trsp-trl. w, gy: gr: bn. Str. w.
 $5 4_1^1$ R, 107.7. Clv. 3 (R), pft. isom. 181.1. Calamine, formerly. Drybone of miners.
 7. Rhodochrosite, Mn. vit-prl. trl. rose, etc. Str. w.
 $4_2 3_1^1$ R, 106.9. Clv. 3 (R), pft. isom. 181.1. Rose spar. Diallogite.
 8. Siderite, Fe. vit, prl. gy, bn, etc. Str. w.
 $4_2 3_1^1$ R, 107.0. Clv. 3 (R), pft. isom. 181.1.

Crystal-faces often curved. Var.: a, crystallized; b, granular; c, massive caucretionary (sphaerosiderite); d, oolitic. Spathic iron ore. Chalybite.

Many intermediate varieties; especially: Mesitite, Mg and Fe; Ankerite, Ca, Ng, Fe.

15. Aragonite, Ca. vit-res. w, gy, gr. etc. Str. w.

3_1^3 2^9 r, pr. M 116.2. Clv. 1 (b), dist, 2 (M), and 2 (D), indist. Mb 121.9, Db 125.8, DD' 108.4 (Fig. 26).

16. Strontianite, Sr. vit-res. w, gy, gr, etc. Str. w.

3_1^3 3_1^6 r, pr. M, 117.3. Clv. M pft, b trs (Fig. 26). DD' 108.2. Isom. 181.15.

17. Witherite, Ba. vit-res. w, y, etc. Str. w.

3_1^3 4^3 r, pr. M, 118.5. Clv. 2 (M), dist. Mb 120.7. Isom. 181.15.

18. Cerussite, Pb. ad-vit, res. w: etc. Str. w.

3_1^1 6^5 r, pr. M, 117.2. Clv. 2 (M), impft. Isom. 181.15.

Many intermediate varieties. Crystals of 15–18 quite frequently compound internally, like snow-star, because MM' nearly 120; visible externally at times, otherwise internally, by polarizing microscope (El. Phys. 296).

20. Barytocalcite, Ca, Ba. vit-res. w, etc: Str. w.

4 3^7 m, nearly R of 106.9. Clv: 3 (R).

200. HYDRATED CARBONATES.

1. Azurite, Cu. 5% water. ad. bl. Str. bl.

$4_2 3_2^7$ m, Clv. 2 pft. 1 dst. 2 tr.

2. Malachite, Cu, 8% water. ad-slk, d. gr. Str. gr.

$3_1^3 3_1^9$ m, indst. fibr. Important ore for Cu.

3. Trona, Na, 22 water. vit. gy. Str. w.

$2^3 2^1$ m. Clv. 1. sol.

F. SILICATES.

201. PHENACITES, R_2O_4Si .

1. Phenacite, Be_2 . vit. clrl. etc. Fig. 32.
 7^3_3R , 116.3 Clv. 3 (M) dst; 3 (R) indst. Rn 160.0
2. Chrysolite, Mg_2 . vit. gr. (olive) etc. Str. clrl.
 $6^3_33^1_1r$. Fig. 18. Clv. 1 (T) dst; M indst. hh 119.2
 Olivin, olivenite; in grains. Also found
 crystallized in meteorites.
3. Willemite, Zn_2 vit-res. y: etc. Str. clrl.
 5^2_4R , 116.0 Clv. 3 (M) dst; 1 (basal) in others.
 Isom. 201.1.
4. Diopase, $Cu.H_2$. vit. emerald gr. Str. gr.
 5^3_3R 126.4. Clv. 3 (R) pft. rr 95.5.

203. ENSTATITES, RO_3Si .

1. Enstatite, Mg. vit-prl. gy: etc. Str. gy
 Fig. 44. 203.3.
 $5^2_33^1_1r$, pr. 87.0. Clv. 2, T, easy, M, K less so.
2. Wollastonite, Ca. vit-prl. w. etc. Str. w.
 $4^3_12^1_1m$. Clv. 1 dst; 1 (110.2 to first) less so.
 Tabular spar.
3. Pyroxene, Mg-Ca-Fe; at times, Al. Pres-
 ence of Fe indicated by color and G. With-
 out Fe w; a little Fe, gr.; shade of gr. deepen-
 ing, till with much Fe, bk. G increases with
 amount of Fe —.
 $5^2_33^3_2m$, Fig. 44. Clv. 2, T, pft. nearly 90° . 2,
 M and K, less so. TT' 87.1; MT 136.4; TK
 133.6; oo' 120.5; PK 106.0. Varieties: a, b,
 $G < 3.4$. c, $G > 3.4$.
 a, Malacolite, Ca-Mg; w, y, to pale gr.
 b, Sahlite, Ca-Mg-Fe; gy:gr. to gr, bk.
 The bright grass gr, trsp. Diallage.
 c, Hedenbergite, Ca-Fe, bk.
 e, Fassaitite, gr, often trsp. } Contain Al.
 f, Augite, bk, bn, deep gr. }

4. Amphibole, Mg-Ca-Fe; at times, Al. See preceding species, which only differs in form, cleavage, and G. Compare genus 181. Fig. 41.

$5\frac{3}{2}3\frac{1}{2}$ m, Clv. 2, T pft, nearly 120° . 1, M, imperfect. TT' 124.5; TM 117.7; PT 103.0; oo' 148.0; Po 145.4, so that o Po' nearly a rhombohedron. Varieties:

a, Tremolite, Mg-Ca; $w.2.9 < G < 3.1$. If tough, fine grained, Nephrite, $H > 6$; also, called Jade.

b, Actinolite, Mg-Ca-Fe; bright gr, gy: gr, $G 3.0-3.2$; usually stellate, fibr. Less than 6% Fe.

c, Asbestos, fibrous var. of above; col. var. mostly w or w: Chrysotile, mountain leather, m. cork, m. wood, different varieties of asbestos. Amianthus, if silky.

d, Pargasite, gr bl:gr, lustrous. } Contain Al.
e, Hornblende, gr:bk, bk. }

205. EPIDOTES, $RO_3Si + \frac{2}{3}R'_2O_3 + \frac{1}{2}Si.O_2$.

1. Zoisite, Ca, Al. prl. gy:w, etc. Str. clrl.

$6\frac{1}{2}3\frac{3}{4}$ r, pr. 116.7. Clv. 1 pft. Crystals usually long, striated lengthwise.

2. Epidote, Ca, Fe, and Al. vit-res. gr, y:gr, br:gr. Str. gy:

$6\frac{3}{2}3\frac{1}{2}$ m, Fig. 42. Clv. 1, M, pft; 1, T, less so, MT 115.4. Tb 128.3, DD 109.5, Mb 116.3.

Slightly diff. from 151.1 (Nitro). Pistacite.

3. Piedmontite, Ca, Mn; Fe, Al; vit-prl. r:bn, r:bk. Str. r:

$6\frac{3}{2}5\frac{1}{4}$ m, isom. 205.2, same clv.

207. GRANATITES, $R'_2O_3 + 3 [RO_3Si]$.

1. Garnet, Al, Fe, Cr; Ca, Mg, Fe, Mn. vit-res. trsp-trl. Col. various. Str. w.

$7\frac{2}{3}3\frac{7}{8}$ t, Clv. 6, dodec. dst: Fig. 9, common com-

bination of d (Fig. 2), and t (Fig. 5), which also occur singly. Chemical name composed of name of prevalent R' and R, in general R¹-R-garnet.

- a, Grossularite, Al-Ca-; $3.4 < G < 3.7$. Colors: w; pale gr; y; bn; cinnamon stone.
 - b, Pyrope, Al-Mg-. Fiery red; Bohem. garnet. Much used as gem; usually found in gravel.
 - c, Alm and ite, Al-Fe-; oriental garnet. precious g.—deep r. trsp. Common g.—bn:r, trl.
 - d, Spessartite, Al-Mn-. G, from 3.7 to 4.4, r. pr.
 - e, Andradite, Fe-Ca. G, from 3.6 to 4.0. Several sub varieties, fine y:, bn: to bk, called resp. Topazolite, Colophonite, Melanite. Allochroite contains also, Mn.
 - f, On var o v ite, Cr-Ca-. Emerald gr. Accurate determination of the variety requires often a careful quantitative analysis; the above represents only the principal types of the varieties actually occurring.
2. Vesuvianite, Al-Ca, mainly. vit-res. gr to bn. Str. w.
- $6^{23}q$ (Fig. 17). Clv. 2, M, dst ? 1, P, less so. Form very nearly t; $\text{Pe } 142^{\circ} 46'$. Several varieties. Idocrase.

211. FELDSPARS, $R\epsilon_4 \text{Al}_2 + 2\text{SiO}_2$ (Fig. 47).

One cleavage, P, pft to em; a second, M, less pft, and nearly at right angles to P. Other cleavages impft. or faint. vit-prl, trsp-trl. w. etc. Str. w.

1. Orthoclase, $R = \text{Ka}_2$, $\epsilon = \text{O} + \text{SiO}_2$ (Ka-Feldspar).

- 6 $\frac{1}{2}$ 2 $\frac{1}{2}$ m. PM 90.0 (Fig. 47). Tl 118.8, PT=Pl=112.2, Tx 110.7.
- a, Adularia, glassy, w. trsp.
 - b, Pegmatolite, vit-res. col. var (r).
 - c, Amazonestone, bright gr.
 - d, compact orthoclase.
2. Albite, $R=Na_2$, $\epsilon=O+SiO_2$ (Na Feldspar)
6 $\frac{3}{4}$ 2 $\frac{6}{7}$ tr. PM 86.4 (Fig. 48). Tl 122.2; PT 114.7; Pl 110.8; TM 117.9.
3. Anorthite, $R=Ca$, $\epsilon=O$ (Ca-Feldspar).
6 $\frac{3}{4}$ 2 $\frac{7}{8}$ tr. PM 85.8 (Fig. 48). Tl 120.5; PT 114.1; Pl 110.7.
4. Other feldspars are composed of the above, grown together in fine laminae, and in various proportions (Tschermak). This is especially evident in Perthite. The different feldspars grow together along M, so that on P they are best distinguished, because PM differs for the different feldspars. Examples:
- a, Perthite, Ka (red) and Na (w) Feldspar.
 - b, Oligoclase, Albite predominates over Ka and Ca.
 - c, Andesite, Albite and Anorthite in nearly equal proportion; but little Orthoclase.
 - d, Labradorite, Anorthite with Albite. Labrador exhibits peculiar play of colors, gr. bl, y dominating.
 - e, Sun-stone, Aventurine, a Feldspar containing minute crystals (of 64.2 ?) which produce fire-like reflections of light.
 - f, Moonstone, a feldspar showing whitish opalescence.
 - g, Obsidian, bk, glassy (volcanic).
 - h, Pitchstone, waxy, amorphous masses, of composition like feldspars. g and h destitute of cleavage.

214. MICARITES. Anhydrous silicates; Ka-Al, etc; Clv. 1 (basal) em! yielding elastic fol. prl-trsp-trl. Str. w. Often in short hexagonal columns, like Fig. 29.

1. *Muscovite*, or Potassium-mica.

$2_1^1 2_2^9$ r, pr. 120.0. Clv. 1, em! light colors (Two optical axes, El. Phys., 295).

2. *Biotite*, or Magnesium-mica.

$2_1^3 2_2^9$ R, Clv. 1, em! dark colors, bk, etc. (One optical axis, El. Phys. 294.)

3. *Phlogopite*, or Magnesium-mica with Ka.

$2_1^3 2^8$ r Clv. 1 em! y:, bn:, etc (two optical axes, near together).

4. *Lepidolite*, or Lithion-mica.

$3_3^1 2_1^9$ r, Clv. 1, em. rose, p, lilac.

220. UNCLASSIFIED SPECIES.

1. *Leucite*. vit. trl-op. gy. Str. chl.

$5_1^3 2^5$ t Clv. 6, dodec. very impft. Crystals, Fig. 5; which is therefore called leucitohedron.

2. *Nephelite*. vit-grs. trsp-op. w, y:, gr:, etc. Str. w.

$5_1^3 2_1^6$ h, Fig. 29. Clv. 3, M, dist.; 1, P, impft. a, Sommite, glassy, small cryst. b, Elæolite, greasy, large, coarse cryst.

3. *Wernerite*. vit-prl; trsp-strl. w. or light, etc. Str. w.

$5_2^3 2_1^7$ q (Fig. 17). Clv. 2, d, dst; 2, M, less so. Scapolite; many varieties.

4. *Lapis Lazuli*. vit. trsl-op. Rich bl. Str. bl.

$5_1^1 2^4$ t, dodec (Fig. 2). Clv. 6, dodec. impft.

221. CYANITES. $\text{Al}_2\text{O}_3\text{Si}$; Polymorphous, as below:

1. *Cyanite*. vit-prl. trsp-trl. bl. etc. Str. chl.

5 to 7. 3_1^6 tr (Fig. 49). Clv. M pft; T, less so. P, impft. TM 106.3; PM 100.8; PT 93.3; Mo 90.3; M dominates; prism. after TM

Striated MP on M. $H=4$ to 5 on M in direction of edge TM, but 6 at right angles thereto. $H=7$ on T and P, especially towards edge PT. Some crystals may be substituted for a compass needle (Plücker) Disthenite, because of varying H.

2. Andalusite, vit-d. trsp-op. w: etc, r: Str. clrl.

$7_1 \ 3_2^3$ r (Fig. 28). Clv. M, impft; 2, tr. MM 90.8; hence, nearly q.

a, Ordinary A-. b, Chiastolite, or macle, H 3 to 7, according to degree of purity. Blackish impurities from rock (shale) distributed regularly in cross sections of crystal, in form of a cross, or otherwise. See figure.

3. Fibrolite, similar to above (1 and 2) but form r. pr. 96 to 98, only 1 clv. very prft.

230. SILICATE-GEMS (except 5).

1. Beryl. $Al_2 [O_3Si + BeO_3Si]_2$ vit-res, trsp-strl. Str. w.

$7^3 \ 2^7$ h (Fig. 29). Clv. P, impft.

a, Emerald, bright emerald gr. from Cr.

b, Beryl, pale gr, bl:, y:, w.

2. Euclase, hydrated Al-Be-Si-ate. vit-prl. trsp. Clrl. pale gr. bl: Str. clrl.

$7^2 \ 3^1$ m (Fig. 46). Clv. T, em. 2, q, impft. ss 115.0; ff 105.8; qq (in zone with f) 49.1.

3. Turmaline. Boro-silicate; charact. by form. vitr. trsp-op. Col. var. Str. clrl.

$7^1 \ 3_2^1$ R (Figs. 35, 36, 37). Clv. tr, R; brittle, esp. crosswise. RR 103.0; oo 133.1; ll 60.0; sl 150.0; ss 120.0. As in figure, crystals often hemihedral: only $\frac{1}{2}$ of equal faces present, also, hemimorphous, the two extremities differing, as in figure.

While changing its temperature, tourmaline has electrical polarity; one extremity + E, the other — E. Figure indicates the E during cooling. This property is termed Pyroelectricity. In direction of axis usually opaque, even if across axis, trsp. Hence, use as Polarizer (El. Phys., 296), plates being cut out parallel to axis. Varieties: a, Achroite, clrl. b, Rubellite, r, rose, ruby. c, Peridot of Ceylon, honey-y. d, Chrysolite, Brazilian emerald, or peridot, gr. e, Brazilian Sapphire, Berlin bl; Indicolite, bl, bl:bk. f, Aphrizite, bk. g, Columnar and black, most common, brittle crosswise.

4. Axinite, Boro-silicate
vitr. trsp-strl. bn: etc. Str. clrl.
 6_1^3 3^3 tr. Clv. 1 dst.; others indst.
5. Staurolite. Al-Fe Si-ate.
vit-res. trl-op. bn, bn:bk. Str. clrl.
 7_1^1 3_2^2 r (Fig. 22). Clv. o dst, M traces. Crystals grow together under 90° or 60° to form crosses. Staurotide.
6. Topaz. $\text{Al}_2(\text{O}_4\text{F}_2)\text{Si}$; Al Si-ate, with Fl.
vit. trsp-strl. y: etc. Str. clrl.
8 3_1^1 r (Fig. 19). Clv. P, pft. MM 124.3; ll 86.9; Ml 161.3; PM=Pl=90.0; Py 117.7; Pf 136.4; Px 138.5; Pu 134.4; Pi 145.8; strongly electric (+E) by friction.
- a, Ordinary in crystals, which, however, nearly always are black, showing only one extremity.
- b, Pycnite, black, columnar.

240. HYDRATED SILICATES; NOS. 3 to 9, are ZEOLITES; 13 to 16, MARGARITES.

1. Calamine, Zn. vit-ad. trsp-trl. w: Str. w.

- $4_1^3 3_2^6$ r (Fig. 25). Clv. M, pft; o, pft; P tr.
 MM 103.8; oo 117.2; pp 57.3; Mb 128.1;
 Pp 118.7; mm 69.8; Pm 124.9; ss 101.6.
 Hemimorphous; compare 230.3; also pyro-
 electrical.
- a, Crystals; implanted on rocks with the py-
 ramid s.
- b, Impure, with carbonate and clay; calamine.
2. Prehnite, Ca, Al, vit. strp-trl. gr: w: Str. w.
 $6_1^1 2_1^9$ r, Clv. 1 dst.
3. Thomsonite, Ca, Al. vit-prl. trp-trl. w,
 bn: Str. w.
 $5_1^1 2_1^3$ r (Fig. —). Clv. M easy; b less; P tr.
 MM 90.7; Mb 134.4.
4. Natrolite, Na, Al. vit, prl. trp-trl. w, etc.
 Str. w.
 $5_1^1 2_1^2$ r, acicular, fibrous, stellate. Fibrous
 Zeolite. Mesotype.
- 4*. Analcite, Al. Na. vit, trsp-op. w: Str. w.
 $5_1^1 2_1^2$ t (Figs. 5, 8). Clv. 3, cube. traces. Analzine.
5. Apophyllite, Ca, Ka. prl-vit. trsp. w, etc.
 Str. w.
 $4_1^3 2_1^4$ q. (Fig. 15). Clv. P em; M pft. MM=
 MP=90.0. Po, 119.5. Ichthyophthalmite,
 fisheye-stone.
6. Harmotome, Ba, Al. vit. w, etc. Str. w.
 $4_1^3 2_1^4$ r, pr. M, 124.8. Clv. 2 (M) and 1, base P.
 Baryte-Harmotome.
7. Phillipsite, Ca, Al. vit. w, etc. Str. w.
 $4_1^1 2_1^2$ r, pr: M, 91.2. Clv. 2, at 90°. Lime-
 Harmotome.
8. Chabazite, Al, Ca. vit. trp-trl. w, etc.
 Str. w.
 $4_1^2 2_1^1$ R. Clv. R, dst. RR 94.8. Gmelinite,
 or Na-Chabazite, similar; angles different.
9. Stilbite, Al, Ca. vit. trsp-trl. w, etc. Str. w.

- 3_1^3 2_1^1 m (Fig. 45). Clv. M pft, N impft. PN 129.7, NT 116.3, PM 90.0. Heulandite, a variety.
10. Serpentine, Mg. res-grs. trl-op. gr: etc Str. w.
 2 to 4. 2^6 a. massive, slaty. Massive.
 a, precious S, rich oil gr, trl. H $2\frac{1}{2}$ -3.
 b, Common S, darker, strl, H up to 4.
 c, Retinalite is resinous. d, Porcellophite has a fracture like porcelain.
 e, Lamellar S, rather rare.
 f, foliated S, Marmolite, fol. brittle.
 g, fibrous S, Chrysotile.
 h, columnar, Picrolite.
 i, Serpentine Rocks, of which the finer varieties are k, Serpentine Marble, often beautifully veined.
11. Sepiolite, Mg. gy: w, y:, r: w. - op.
 2_1^1 - 0.9, floats on water! Smooth feel, earthy or clayey texture. Meerschaum.
12. Talc, Mg. prl-grs. trsp-strl. gr: etc. Str: w.
 1_1^1 2_1^1 r. Clv. 1, em! fol. gran. Feel, greasy.
 a. Foliated Talc. b. Steatite, Soapstone, massive, gy:, gr:. Coarser kind: c. Potstone, finer grained. d. French Chalk.
 e. Indurated Talc is harder, impure. f. Talcose Slate, argillaceous rock, containing talc enough to impart the greasy feel.
13. Chloritoid, Al, Fe. prl. trsp-trl. gy, gr.
 5_1^3 3^5 m. Clv. 1, em. fol. brittle.
14. Margarite, Al, Ca. prl. trl-strl. gy:, y:.
 Str. w.
 4_2^0 3 r. Clv. 1, em. fol. brittle. Pearl mica.
15. Penninite, Al, Fe, Mg. prl-vit. trsp-strl. Col. var. Str. w.
 2_1^1 2_1^1 R, 65.6 (Fig. 38). Clv. P, em. Laminæ flex., not elastic.

16. *Ripidolite*, Al, Mg, Fe . prl. trsp-trl. deep. gr. Str. gr: w.
 $2\frac{1}{2}$ $2\frac{1}{2}$ m. Clv. 1, em. Laminae flexible, somewhat elastic. Chlorite, Clinocllore.
17. *Prochlorite*, Al, Fe, Mg . prl. trsp-trl. gr. Str. gr:.
 $1\frac{1}{2}$ $2\frac{1}{2}$ h. Clv. 1, em. Lam. flex., not el. Chlorite.—Crystals often implanted on edge.
- Dichroism*. — The green minerals 15, 16, 17 often appear red, if seen in the direction of cleavage. Compare 81.1.
20. *Kaolinite*, $\text{Al}_2(\text{O}_3\text{Si})_3$; H_4 replacing one Si. prl. d. trsp-trl. gy: y: bn: etc. Str. w.
 1 to $2\frac{1}{2}$. $2\frac{1}{2}$ r, minute plates, nearly hexag. Kaolin. Porcelain Clay.—Bole, r.
- Clays are impure hydrous Aluminium silicate.
 Fire-clay, Pipe-clay, Clay, Loam.

Class IV. Fluorides.

- 271** 1. *Fluorite*, Ca Fl_2 . vit. trsp-trl. Col. var. Str. w.
 4 $3\frac{1}{2}$ t (Figs. 3, 6, 5, 1). Clv. 4, octah. pft.
 Numerous forms and beautiful colors; hence, *Erzblume* (ore flower) of older miners, esp. as it accompanies many valuable ores. gr, bl, purple; due to organic coloring matter.
- 275.** 1. *Cryolite*, $\text{Na}_3\text{Fl}_6\text{Al}$. (*Na Fluo-Aluminate*)
 vitr, strsp-trl. w.; at times bn, etc. Str. w.
 2^2 3 tr. Clv. 3; 1 pft, the other 2 less pft; mutually nearly at 90° .
- 281.** 1. *Halite*, Na Cl . vitr, trsp-trl. w, y: r: bl: Str. w.
 2^2 2^2 t. Clv. 3, cube, pft; sol. Rock Salt.
- 281.** 2. *Cerargyrite*, Ag Cl . res-ad. trsp-trl. gy: etc. Str. shining.
 $1\frac{1}{2}$ $5\frac{1}{2}$ t [h, o, d]. Clv. none. Sectile. Horn Silver. Corneous Silver. Important Silver Ore.

290. 1. Carnallite, $KaCl_3Mg+6H_2O$.
 2^2 1.6 gran., mass. milk w; r; sol.
290. 2. Atacamite, $Cu, Cl, Hydrate$. ad-vit. trl-
 strl. gr, bright. Str. apple-gr.
 $3\frac{1}{2}$ $4\frac{2}{3}$ r, pr. 112.3. Clv. 1 pft, 2 impft.

Appendix. Combustibles.

A number of mixtures (96) of different serials (119) occur in large quantities; several of these mixtures are very largely used as fuel by modern industry. Hence, although most of these substances rather belong to the rocks than to the minerals, it is advisable to give a short characteristic of the principal members at this place.

All but anthracite burn with flame, the flame being due to the combustion of the volatile bitumen. Pure bitumen consists of C and H, and is fusible and inflammable.

I. MINERAL COAL. Blackish, solid; dull to sub-metallic. Brittle. Infusible — some softening upon heating. Insoluble in benzine. $H \frac{1}{2}$ to $2\frac{1}{2}$. G 1 to 1.8.

1. Anthracite. $H=2\frac{1}{2}$; $G=1\frac{3}{4}$ sm, glistening, often iridescent. Black. Only to three per cent bitumen; no or feeble, pale flame.

2. Bituminous Coal. $H=2$, $G=1\frac{3}{4}$. Black, resinous luster, compact, firm, more brittle than 1. Varieties:

- a. Caking Coal; becomes viscid when heated in open fire or covered crucible; residue left in latter case is Coke.
- b. Non-Caking Coal; heated in crucible yields no coke, but fragments retain their form.
- c. Cannel Coal (either to a or b); no luster, dull, black, smooth surface of fracture; yields much burning oil when heated while air is excluded (dry distillation). Torbanite is a brownish cannel coal.

3. **Brown Coal**, usually less hard than the preceding, $G=1\frac{1}{2}$. Brownish to bn:bk, non-caking, often quite bituminous. Lignite is a brown coal retaining the structure of wood*. Jet is a black, compact brown coal, susceptible of high polish. Earthy brown coal, rather friable. All brown coal yields an acid distillate, while black coal (No. 2) yields a distillate of alkaline reaction. Brown coal powder, boiled with potassium hydrate, colors the solution brown.

Amber is a fossil resin; r, bn; w, to pure y. Str. w. trsp—trl. $H=2\frac{3}{4}$ — $G=1.06$ to 1.08 . Strongly—E on friction. Fuses 290° . Amorphous. Insoluble in alcohol and ethereal oils. Burns with yellow flame. Yields, upon heating in a closed tube, a whitish sublimate of succinic acid; the residue is soluble in ethereal oils.

II. BITUMEN. Black, lustrous, fusible solids, or liquids. Soluble in benzine. Highly inflammable.

4. **Asphaltum** (mineral pitch). $G=1.0$ to 1.8 . Pitch luster; black; readily fusible at about 100° . Ozocerite, $G=0.85$ to 0.90 , fuses at about 60° ; trl.; greasy to the touch.

5. **Pittasphalt** (mineral tar). Viscid mass; $G<1$.

6. **Petroleum**, more or less limpid. $G<1$. Yields different coal oils by fractional distillation, as Kerosene, $G=0.8$. Gasoline, $G=0.7$. Compare note to 119.

All these native materials, being not species (see 223), but merely mixtures (96), pass gradually into one another. They are also occurring in various rocks, such as limestones, and especially shales. Such shales yield bitumen upon distillation, and are used for the manufacture of coal oils.

*Mineral charcoal, black, soiling the fingers, rather fibrous, woody texture. Small quantities occur in the mass of other mineral coals.

CHAPTER VIII.

THE CHEMICAL SCHOOL LABORATORY.

235. The motto placed at the head of this volume occurs in the description of the grand Laboratory of the University of Leipzig, published in 1868 by the director of that Laboratory, Prof. H. Kolbe. The motto asserts that chemistry cannot be learned from books, nor even by attending chemical lectures (with experiments performed by the professor before the class), but only by diligently working in the Laboratory.

Hence the importance of a Chemical Laboratory for every school where chemistry is to be taught.

236. But the students cannot be sent into the Laboratory at the very beginning; at least a class of students cannot. They must first become familiar with a multitude of facts and things by sight, before it is possible to trust them to handle the apparatus. We have adopted the following order in our instruction, which combines lecture, recitation, and laboratory work, closing with a thorough examination.

237. I. The class is assigned a lesson of twenty-five or twenty pages, preparatory to attending the lecture on the same. At this lecture the apparatus described in the lesson is exhibited, some of the experiments are performed (especially all such as are not intended for students' practice). By casual questions, the teacher ascertains whether the students have studied the lesson sufficiently to follow him with advantage. Finally, in this lecture the teacher obtains an opportunity to produce that impression on the student which no printed page can produce; thereby the real advantages of the lecture-system are secured.

In these lectures the teacher may also add such general

views and special considerations as his own reading and practice may suggest. Above all, the teacher should make the most of his apparatus and collections in these lectures, which thus will not only be highly instructive, but also attractive and deeply interesting.

238. II. These lectures are immediately succeeded by regular recitations, wherein each point is carefully examined. On the average, two recitations are required to pass properly over the ground covered by one lecture. In these recitations the students are properly expected to know each apparatus described—for they have in the meanwhile again studied the description in the book, after having seen the apparatus in the hand of the teacher during the lecture. In these review-recitations especial attention must be given to all directions for work in the Laboratory, so that the students may know how to handle the apparatus before entering the Laboratory. In these recitations the students' answers should, of course, be carefully marked on the class list. Thus the advantages of the so-called recitation system are secured in our mode of instruction in chemistry.

239. III. In two, or at most three, weeks, the class will thus have been instructed in a sufficient portion of the book to be able to commence *Laboratory Practice*. That is, after having secured the advantages of both the more common systems of instruction by lectures and recitations—each student commences in the laboratory a close and careful personal and experimental study of the phenomena and facts of chemistry, which thus far he had only witnessed “from afar off,” or merely read and talked about. Thus the double course of instruction preceding this laboratory practice is to us only preparatory, fitting the student to profitably work in the laboratory—while in too many schools but one of the preceding modes of instruction is all that is given.

240. It will invariably be found that students, in many particulars, fail to do as directed, and as they themselves have learnt during lecture and recitation. Hence constant supervision during laboratory practice is absolutely nec-

essary, to refer the students to the proper directions in the book, and to see that everything is done in a proper way, in accordance with the laboratory rules. No one, who has not actually tried it, will believe how very great the difference is between word and deed; between "talking about" a thing from book-study, and doing the work in a laboratory.

241. The student should enter a careful—concise and clear and neat—record of his experiments in the "Journal of Experiments" bound with this volume. In trying to do this, the teacher will find a great obstacle in the exceeding carelessness prevailing in most schools in regard to the writing of both words and figures.

All work done in the laboratory must be immediately recorded by the student in his Journal of Experiments, and, before leaving the laboratory, this record must be exhibited to the superintending teacher, who enters the current number of his pocket record-book, while at the same time he enters the article worked and the name of the student opposite that number in his own pocket-record*. This is nec-

* We write all numbers like fractions, the tens as numerator, the units as denominator; thus No. 1572 is written 157.2 in the student's Journal. A page of such record looks like the following, copied from Mr. Nipher's pocket record-book:—

1871, Oct. 16.

518/0 Tolles, 14.

1 Conley, 28, a.

2 Bowman, 104, a.

3 Ingram, 90, C.

4 Miss Sanders, 44, d.

5 Miss Tanner, 114, c.

6 Walker, 28, c.

7 Kling, 94, a.

8 " 120, a.

9 Miss Cool, 106.

519/0 East, 120, b; 94, b.

1 Forrester, 28, c.

essary, because the student's Journal of Experiments—not only in regard to quantity, but also in regard to quality of the work done and the neatness of the record itself—enters largely in the final class standing of the student at the close of the term.

If the laboratory work is carried on in this manner, then the students become personally familiar with the facts, they learn to deal with realities, and thus really study chemistry, instead of merely a book*.

242. IV. At the close of the term, the student passes an examination, at least on the general contents of the book and the full details of those portions which he has practiced. Compare *El. Phys.*, 487, note.

243. The minimum of time to be devoted to these different portions of the subject is, in hours per week: Lecture, one; review-recitations, two; laboratory practice, two. The latter ought to be consecutive hours. Since no preparation is required for these hours of practice, outside of that afforded for the lectures and recitations, each two hours practice is equivalent (in time) to one hour recitation; for the latter does at least require one hour of previous study at home on the part of the student. Accordingly—on the basis of equivalence to FIVE HOURS recitation (requiring five hours preparation) per week, the study of chemistry should be divided thus per week:

Lecture—one hour, requiring one hour preparation.

Recitations—two hours, requiring two hours preparation.

Practice, twice—two hours, requiring no extra preparation.

Total at school, seven hours; at home, three hours; in all, ten hours per week.

244. For the demonstration of any given article of this book, the student is furnished with the necessary set of apparatus, designated by the number of that article. Different sets for the same article are distinguished by letters

* Chemistry and Physics, as usually taught by mere lectures or recitations, are not Physical Science, but only additional literary studies.

added. The pieces of apparatus or material are designated by the numbers 1, 2, 3, etc., following the number of the article. A card-label accompanies each set of apparatus, and contains a complete enumeration of all pieces. These labels are also copied in the general inventory of the laboratory. Each piece of apparatus has (if possible) a small label, composed of number of article (with letter) and number of the piece. Compare *El. Phys.*, 496.

The following may serve as an example of such a card-label:

64^b. Gradual Heating and Boiling of Water.

1. Glass flask.
2. Rubber stopper, double perforated.
3. Short, wide glass tube.
4. Thermometer, No. 7.
5. Sand-bath, with sand.
6. Tripod.
7. Alcohol lamp (glass).
8. Beaker with fresh water (not yet boiled).

For time, observe a good watch with second hand.

The tube (3) should pass through one of the holes of (2) while the thermometer (4) passes through the other.

The label on the alcohol lamp will thus be $\frac{64^b}{7}$;

on the beaker, $\frac{64^b}{8}$.

245. Large apparatus, — like balance, barometer, etc., — do not, of course, accompany each set, but are put up in convenient places of the laboratory for general use. The wash-stand and general heating apparatus belong also to the apparatus, of which but one need be provided for the entire laboratory.

A wash-stand is absolutely necessary. A simple, covered round tank, placed a meter above a wash-stand, with faucet, wash-bowl, and drain will answer. The drain may even be omitted. A large, earthen jar, for the reception of filter, burnt matches, etc., may find a proper place under this wash-stand.

A common American Cooking Stove (for wood) will answer excellently as a general heating apparatus. The oven will serve as air-bath. On the last two holes a pan for irons may be placed, containing sand; this forms a capacious sand-bath (18). On the two holes directly above the flame, a boiler, with faucet, may be placed, so that water (for washing and experimental purposes) is always at hand. The boiler may be provided with holes and rings, so as to be used as water-bath (19); also, with tubes and condenser (59), so that distilled water may be made in the room.

The Kerosene Stove, patented by R. B. Mitchell,* will be exceedingly useful in all school laboratories not provided with gas. His stove No. 1 is easiest managed; No. 3 is most effective, but also most expensive. None of the more expensive furnaces are at all required for schools teaching these elements of chemistry.

246. The sets of apparatus should be properly distributed on the work-table, for the students' use. The students pass from one apparatus to another, and the apparatus is removed when all the students, or a sufficient number of the same, have performed the experiments therewith. A new apparatus takes the place of the one removed.

247. If the work-table—which may be the same as used for the elements of physics†—is provided with shelves, and especially with doors, the apparatus not in use may be preserved on the shelves or in these cupboards. Otherwise, some cases, or a separate room with cases, ought to be provided for that purpose.

* Winchester Avenue, 45, Chicago.

† 80 cm. high, and 60 cm. wide (El. Phys., 491.)

248. A separate laboratory is not absolutely necessary for small schools; for the work-table may run along one or more of the walls of the room, especially along the wall containing the windows. If a room adjacent to the school room is at disposition, it should be used as store-room, and as the teacher's laboratory, where apparatus and specimens can be prepared and preserved. Even larger schools do not absolutely require a laboratory, separate from the lecture or recitation room; for if the room is properly ventilated,* the air will not be vitiated by the experiments required in this book.

249. Much of the practice may also be performed at the common school-desk; especially all practice in Chapter VII.; also, 205, 206, etc., etc. By a judicious distribution of the work, a comparatively large number of students may practice at the stands along the work-table, and at the common school desks.

250. For further information on these topics, we refer to the first pages of the "Journal of Experiments," and especially to the quarterly journal,—*"The School Laboratory of Physical Science,"*—edited by the author. This journal, while of great practical importance to the teacher, is also of considerable use to the student, because it regularly brings series of laboratory work done by students.

* If not properly ventilated, the room is not fit for recitation room either. Our school boards, school directors, and even Christian presidents of colleges are, however, very generally guilty of poisoning the children by vitiated air, due to the absence of proper ventilation in the rooms under their control.

JOURNAL OF EXPERIMENTS

IN

HINRICHS'

ELEMENTS OF CHEMISTRY

AND

MINERALOGY,

PERFORMED IN THE

SCHOOL LABORATORY,

UNDER THE DIRECTION OF

BY

AT

LABORATORY RULES.

1. BE QUIET.—Talk not to your fellow students, and only in low whispers to your teacher. Walk to and from the balance so that your steps are not heard. Early learn thus to show reverence for truth and its investigation; the laboratory should be a temple of science.

2. BE CERTAIN.—Do everything so that no doubt can arise. Measure, weigh, and record as directed, then you will be sure. Do not trust to your memory. Do not assert anything of which you are not sure. Never *guess*—at most, estimate.

3. BE CAREFUL.—Handle every apparatus precisely as directed, and as if it would require a fortune to replace it. See that everything is in good order when you receive it, and take pride in returning the same in excellent order to your teacher.

4. Breakage of apparatus and waste of materials must immediately be reported and paid for, the student countersigning in the Laboratory Journal the amount paid.

5. Throw nothing on the floor; put refuse matters in the stone jars, not into the wash-bowls.

HOW TO KEEP THE JOURNAL.

Page this journal as a continuation of the book. At the upper right hand enter the date, at the upper left hand the article of the book to be demonstrated by your experiment. As heading of page, write concisely and plainly the subject investigated. On the proper place, in the margin of the text, enter the number of the page of the journal where these experiments are recorded. In this manner, you can readily turn from the text to the experiments, and from the experiments to the text. Never omit doing this. The author only directs your work,—you discover the truth of the laws for yourself.

Keep your journal perfectly clean and nice, write plainly and elegantly; do not crowd words and figures together, but leave ample room in margin.

Be *concise and precise* in all your written statements; avoid all superfluous words. Freely use proper abbreviations, such as given in 231, and also, the following:—

Bp.	Blowpipe.
Ch.	Charcoal.
Sd.	Soda.
Fltr.	Filtrate.
fltr.	filter.

Pr.	Precipitate.
pr.	precipitate.
sol.	Soluble.
Sol.	Solution.
insol.	insoluble.

EXPERIMENTAL DEMONSTRATIONS IN THE ELEMENTS OF CHEMISTRY.

As soon as an experimental demonstration has been performed, cancel the corresponding number or letter in this list by a cross (X), in pencil, so that your teacher, at a glance, can see what experimental demonstrations you have completed.

HEAT.

BLOWPIPE: 23. 24₅. 26₇. 28.

RADIATION: 33. 34₅. 41.

THERMOMETER AND CALORIMETER: 38. 44. 45. 50.

FUSING AND BOILING: 60. 61. 63, a, b. 64, a, b. 67. 68.

CHEMISTRY.

DISSOCIATION: 93, a, b, c. 94. 95.* 99. 101. 102. 104.

ELEMENTS AND COMPOUNDS: 116, a, b, c, d, e, f, g, h, k, l. 117, a, b, c, d, e, f, g, h, k, l.

ACIDS AND BASES: 133₄. 136₇. 141₂. 150-3, a, b, c, d. 155. 157₈. 159.

SYNTHESIS: 166, a, b. 167, a, b, c. 168. 169. 170.

SUBSTITUTION: 172-3, a, b, c, d, e, f, g, h. 174, a, b, c, d. 175, a, b, c, d, e, f, g, h. 176. 177. 180. 181.

DOUBLE DECOMPOSITION: 190, a, b, c. 191. 192. 193. 196. 197. 198. 199. 200. 201. 202. 205, a, b, c, d, e, f, g, h. 206-7, a, b, c, d, e, f, g, h. 208.

COMPLEX PROCESSES: 213. 215.* 216.

MINERALOGY.

[Enter the species and variety determined after the number of genus printed.]

GENERAL DETERMINATION :

ELEMENTS: 1 — 2 — 3 — 4 — 5 —

SULPHIDES: 11 — — 12 — 15 — — 18 — — 21 — 22 — 30 —

SULPHOSALTS: 31 — 41 — 45 — —

OXIDES, SINGLE: 61 — — — — — — — 64 — — — — —
67 — 71 — 80 —

METALLOSALTS:	81	—	—	82	—	83	—	—	84	—	—	88	—	90,	91.
SULPHATES:	101	—	—	—	111	—	130	—	—	—					
PHOSPHATES:	135	—	141	—	150	—									
NITRATES:	151	—													
BORATES:	161	—	165	—	171	—									
CARBONATES:	181	—	—	—	—	—	—	—	—	—	—	200	—	—	
SILICATES:	201	—	203	—	—	—	—	205	—	—	207	—	—	—	—
	211	—	—	—	214	—	—	220	—	221	—	230	—	—	—
	—	240	—	—	—	—									
FLUORIDES:	271	—	275	—	281	—	290	—							
COMBUSTIBLES:	1	—	2	—	3	—	4	—	5	—	6	—	—		

DETERMINATION OF CRYSTALS.

TRICLINIC:	130	5.	161	1.	211.	213.	221	1.	230	4.												
MONOCLINIC:	111	1.	130	4.	171	1.	200	1.	204	2 3 4.	205	2 3.	211	1.								
													230	2 5.								
RHOMBIC:	11	2	18	1.	45	3.	101	2 3.	151	1.	181	15 16.	201	2.	205	1.						
													214	1 3.	230	6.	240	1 6 7.				
QUADRATIC:	31	1.	61	3 4 6 7.	83	1 2.	220	3.	240	5.												
RHOMBOHEDRAL:	45	1 2.	61	1.	64	1 2.	151	2.	181	1 2 3 4 7 8.	201	1 3.										
													214	2.	230	3.	240	8.				
HEXAGONAL:	71	10.	135	1 2.	220	2.	230	1.														
TESSERAL; a, holohedral:	15	1 2.	41	2.	71	1.	81	2 3	84	1.												
													207	1.	220	1.	240	4.*	271	1.	281	1.
b, hemihedral:	11	1.	41	1.	165	1.																

PROBLEMS.

Reductions,	39	—	—	Expansion,	40	—	—
Heat and Combustion,	46	—	47	—	—		
Heating by Steam,	69	—	—	Pressure of Vapors,	72,		
	—	—	Steam Engine,	78,	—	—	
Substitution,	183	—					

Each experiment performed, determination made, or problem solved, should be canceled on this check-list; so that this list, at a glance, shows what has been done in practice.

Exhibit this check-list to your instructor whenever new work is to be assigned to you.

GENERA.		SPECIES.				
Γ'	H.....					
1 $K\alpha$	Li	Na	Ka	.	..	
2 $X\alpha$	..	..	Ca	Sr	Ba	
3 $K\delta$	..	Mg	Zn	Cd	Pb	
$\Gamma\gamma$	..	..	.	..	Hg	
4 $K\upsilon$	..	..	Cu	Ag	Au	
5 $\Sigma\epsilon$	..	Al	$\Sigma\delta$	Rh	Ir	
6 $T\tau$	C	Si	Ti	Pd	Pt	
..	Bo	..	..	Sn	..	
7 ϕ	N	P	As	Sb	Bi	
8 θ	O	S	Se	Te	..	
9 X	Fl	Cl	Br	Io	..	
Γ	H.....					
$\Sigma\delta$	Cr	Mn	Fe	Ni	Co	Ur

GENERA.		SPECIES.				
	I'	H.....				
1	$K\alpha$	Li	Na	Ka	..	..
2	$X\alpha$	..	..	Ca	Sr	Ba
3	$K\delta$	..	Mg	Zn	Cd	Pb
	$I\gamma$	..	..	..	..	Hg
4	$K\psi$	..	..	Cu	Ag	Au
5	$\Sigma\epsilon$	..	Al	$\Sigma\delta$	Rh	Ir
6	$T\tau$	C	Si	Ti	Pd	Pt
	..	Bo	..	..	Sn	..
7	ϕ	N	P	As	Sb	Bi
8	θ	O	S	Se	Te	..
9	X	Fl	Cl	Br	Io	
	I'	H.....				
	$\Sigma\delta$	Cr	Mn	Fe	Ni	Co Ur

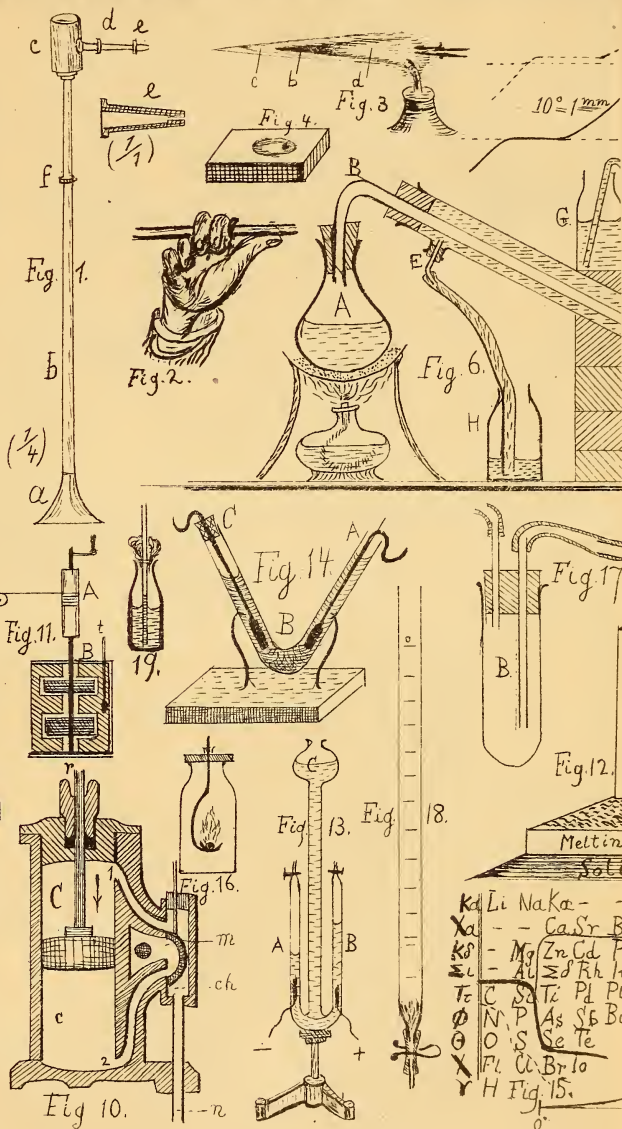










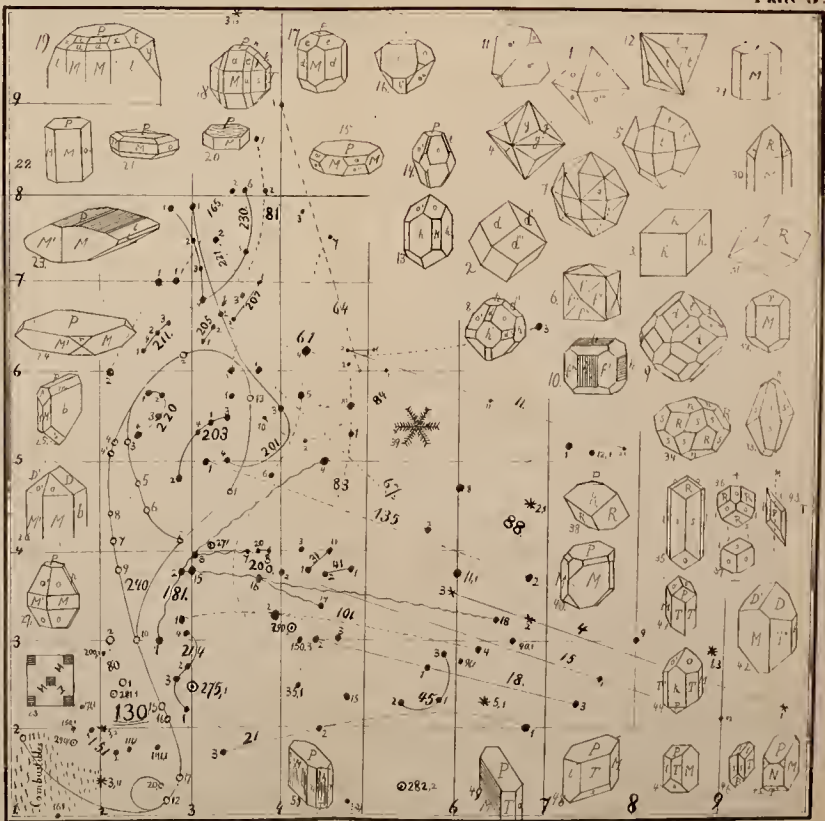


§. 185. πV volat.
 $\pi V'$ non volat.

Chemical Reactions.

§. 152.
 $Ka H\text{-}ate \rightarrow H H\text{-}ate$
 $H S\text{-}ate \rightarrow Ka S\text{-}ate$

Ka	Li	Na	Ka	-	-
Xa	-	-	Ca	Sr	B
Ka	-	Mg	Zn	Cd	P
ΣL	-	Al	ΣS	Rh	In
Te	C	So	Te	Pl	Pe
Φ	N	P	As	Sb	Bi
Θ	O	S	Se	Te	
X	Fl	Cl	Br	Io	
Y	H				

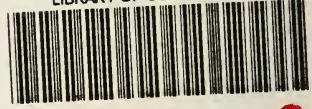








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